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FRIS

FOREST RESOURCE INFORMATION SYSTEM

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ST REGIS

SOUTHERN TIMBERLANDS DIVISION

FOREST RESOURCE INFORMATION SYSTEM

FRIS

FINAL PROJECT REPORT

Prepared as a Final St. Regis Document on FRIS
(Forest Resource Information System)
A Cooperative Project Between the
National Aeronautics and Space Administration
and St. Regis Paper Company
February 1, 1983

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Southern Timberlands Division

TABLE OF CONTENTS

Table of Contents (continued)

Table of Contents (continued)

FINAL REPORT NASA

LIST OF FIGURES

List of Figures (continued)

FINAL REPORT - NASA

LIST OF TABLES

FOREST RESOURCE INFORMATION SYSTEM

FRIS

FINAL PROJECT REPORT

-ABSTRACT-

A Final Report is presented on the cooperative project, Forest Resource Information System (FRIS) entered into by the National Aeronautics and Space Administration (NASA) and St. Regis Paper Company (STR). Technically supported by Purdue University's Laboratory for Applications of Remote Sensing (LARS), the project, of three years duration, was designed to evaluate the technological and economical feasibility of using multi-spectral digital image data as acquired from the Landsat satellites in an ongoing operational forest information system. Modular in design, the project progressed through four phases: start, demonstration, systems transfer and implementation.

Computer compatible multi-spectral scanner data secured from the Landsat satellites were demonstrated to be a significant contributor to ongoing information systems by providing the added dimensions of synoptic and repeat coverage of the Earth's surface. Major forest cover types of conifer, deciduous, mixed conifer-deciduous and non-forest, have been classified well within the bounds of the statistical accuracy of the ground sample. Further, when overlayed with existing maps, the acreage of cover type retains a high level of positional integrity.

Digital image processing is not a stand alone technology. Maps were digitized by a vendor provided Graphics Design System, overlayed and registered onto Landsat imagery such that the map data with associated attributes were displayed on the image. This is of great value in analyzing Landsat data. Once classified, the analysis results were converted back to map form as a cover type layer of information.

Existing tabular information as represented by inventory is registered geographically to the map base through a vendor provided data management system. The notion of a geographical reference base (map) providing the framework to which imagery and tabular data bases are registered and where each of the three functions of imagery, maps and inventory can be accessed singly or in combination is the very essence of the FRIS design.

The additional cost required for FRIS through expanded computer capabilities and the addition of the image processing function is more than offset by the efficiencies gained. Efficiencies will be realized through ground sample allocation and design, aerial photographic mission design and in meeting the divisional mapping requirements.

ACKNOWLEDGEMENTS

The scope of the FRIS project and its ultimate implementation as an operational system, transcends the technical expertise of any one individual. The FRIS Project Manager and editor of this final report is grateful to a number of individuals who together make up the FRIS project team, and without whom, this report could not have been written. Within the St. Regis organization, special thanks go to Al Beecher and Micha Brym of the MIS department and Samuel Suh of the Technical Operation Division for their help in the systems design configuration. The editor's thanks again to Al Beecher who along with Bill Shelley and Bud Goodrick, were instrumental in transferring the software to, and installing the hardware at the Divisional FRIS Center.

The key to the Systems acceptance by management and implementation by St. Regis was the economic analysis. The editor's gratitude is extended to Cleatus M. Turner who provided the guidance and down-to-earth realities in the potential implementation options. Special thanks are also due to the other members of the FRIS Project Steering Committee, Dick Mroczynski of LARS, whose insistance on a team approach throughout, was a key to the project's success and Rig Joosten, the NASA Project monitor, whose patience and understanding provided the necessary latitude required for success. The FRIS manager is especially indebted to Sonja Brockman for her tolerance and patience in typing and editing the manuscript.

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FRIS Manager

FOREST RESOURCE INFORMATION SYSTEM

FINAL PROJECT REPORT

1.0 INTRODUCTION

1.1 SUMMARY

This report documents the results, from the standpoint of St. Regis Paper Company of a three year project to assess the feasibility of utilizing satellite acquired data in a day-to-day operational information system.

The project, Forest Resource Information System (FRIS), was a cooperative endeavor between the National Aeronautics and Space Administration (NASA) and St. Regis Paper Company (STR). Technical support for the project was provided by Purdue University's Laboratory for Applications of Remote Sensing (LARS). Designed in modular form, FRIS was to first demonstrate the technological and economic feasibility of incorporating digital image data into an operational information system. Upon STR management's approval, a systems transfer phase was then to be undertaken to transfer existing systems with documentation from LARS, and to structure a system design configuration compatible with STR operations, in a production environment. The final phase of the project, implementation, represented the withdrawal of NASA and LARS from the project with the entire system being turned over to STR personnel as a wholly owned, in-house system (6).

This report summarizes the rationale and approach to the project, the results and conclusions reached, and St. Regis' actions taken in response.[1]

1.2 BACKGROUND

With the intensification of forest management practices in the post World War II years, a significant part of the industrial forest management resource has been allocated toward providing information on the forest complex. This information base has been specifically built in terms of quantitative standing timber values, patterns of stand structure and conditions and to those variables contributing to the dynamic responses of the forest over time.

<u>Quantitative Timber Values</u>

Quantitative timber values are those measureable quantities of interest defining timber as a raw material in terms of commercial units of value (cubic feet, board feet, ton, etc.). These quantitative parameters are important not only in describing the gross raw material availability as a single value, but also in providing a measure for alternative uses possible from the timber supply on hand.

[1] Where possible and practical, metric units are used as the standard with common units in parentheses.

Stand Structure and Condition

Very seldom is a forest described as a whole, but rather as an aggregation of many forest cover type components, occurring as a result of natural forest progression, or from conditions resulting from man's cultural activity. While quantitative timber values describe the sum of individual tree measurements, stand structure and condition describe the timber stands as producing entities.

Structurally, timber stands are described and evaluated as to species composition, or cover type, timber size and conditions, age classes of significance and density of stocking. Conditional aspects reflect the environmental situation under which the timber is growing, and the productivity potential as indicated by topographic position and growing site. Stand condition also describes the degree of competing vegetation, past cultural activity and overall well being of the stand. Stands, then, are timber associations with individual quantitative values and growth characteristics.

Dynamic Response of the Forest Over Time

Dynamic response refers to the growth and net change occurring throughout the forest complex over measured periods of time (growth periods). The impact of net growth and the associated effect of man's cultural activity as expressed in harvest and regeneration describes the net change occurring during the time span of interest. These bio-cultural aspects vary depending upon current operational practices which may have profound implications in the future structure of the stand, and in total reflect the dynamic response of the forest to natural and man-induced activity.

1.3 RATIONALE

The data required to measure and establish those parameters of quantitative value, stand structure, growth and net change, are broad indeed. To acquire these data at a level of precision commensurate with the needs of management in the decision making process becomes a problem of major proportions. To alleviate the physical data acquisition activity associated with the adequate definition of the forest, constituted a major thrust of the project. The problem as perceived was couched in three major considerations.

Need for the Data

The need for up-to-date information on the quantities and qualities of timber, the condition of the land base in which it grows and the estimate of the nature and rate of its change is greater today, in the 1980's, than ever before in the history of modern forest management in the United States. Listed below are some of the factors contributing to this need.

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Financial Alternatives - The recognition by management both public and private of the vast capital resources represented by timberlands and that the availability of new lands have become exceedingly scarce , forcing a dependence on lands already controlled. The alternatives for management are so varied, options must be weighed in terms of financial return relative to the objectives of management, if the land is to be managed at its optimum.

Reliable forecasting including time spans of 20-30 years and longer are essential to properly evaluate the options. Since inaccuracies magnify rapidly when adding the ingredient of time, the quality of data used as input becomes vital.

Increase in Timber Demand - The demand for wood products, increasing with the growing population has reached new highs, and the supply has become exceedingly short for at least the present.

The Outlook for Timber in the United States as of 1970, released by the U.S. Department of Agriculture (1973) showed the demand for wood products over the last three decades increasing substantially (8). This report also suggested an increase from the 1976 level of 13.3 billion cubic feet to 22.7 billion cubic feet annually by the year 2000. It is expected that a high percentage of this incremental demand for wood will have to be provided by the southern forests. The publication, The South's Third Forest (1969), predicted the timber cut in the South in the year 2000 will be 2.3 times that of the annual cut (1968) (5). This prediction includes a 2.5 fold increase in softwood and a 1.9 fold increase in hardwood production during this period.

Decrease in Land Base - in 1970 the South had 77.7 million hectares (192 million ac.) of commercial forest land. Federal, State and County governments owned nine percent, forest industry 18 percent and 73 percent were held by miscellaneous private landowners· Figure 1.

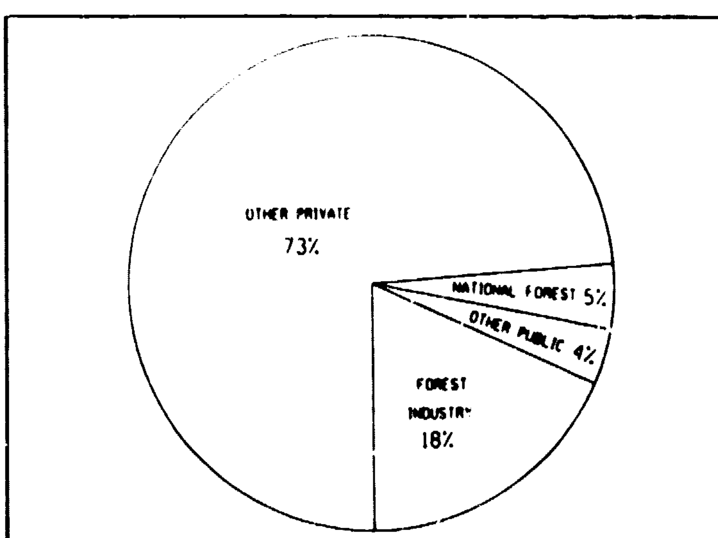

Figure 1 - Southern Commercial Forest Land by Percentage of Ownership

The rising demand for timber is going to require the judicious use of all timbered lands since the projected future land base is expected to decrease. It is of interest to note that the Forest Service reported the land base was decreasing and predicted it would reduce the commercial forest land in the South from 77.7 million ha (192.7 million ac.) in 1970 to 76.2 million ha (188.3 million ac.) by the year 2000. This estimate was revised in 1980 in An Analysis of the Timber Situation in the United States 1952-2030 (9). This report, reflecting statistics as of January 1, 1977, shows the commercial timber land base at 76.1 million ha (188.1 million ac.) at that point (1977). This suggests an annual loss to other than timber uses greater than 101,215 ha (over a quarter of a million ac.) per year. This is in dramatic contrast to the 58,300 ha (144,000 ac.) loss per annum predicted in 1973. Faced with this squeeze between increased demand and decreasing land base, elevated production levels will have to be achieved if future fiber requirements are to be met.

Demand for Alternative Uses of Land - More spectacular than the increase cited in demand for timber has been the increase in demand for recreation and non-timber uses of the forest. This, of course, overlaps somewhat with the decrease in land base. The effect of urban "sprawl", the encroachment on commercial timberlands by recreational activities, curtailing of operations, or modifying highly productive levels in the interest of "multiple-use" or "ecology", requires a careful monitor on forest conditions so reasonable compromises can be reached while still achieving the goal of timber production required for the future.

Timeliness of the Data

To be effective as a management tool, information must be current, responsive to change and accessible in a user compatible form. To achieve this, three conditions must exist:

1. Efficient and rapid data capture, reduction, and analysis procedures to establish and selectively reestablish the data base as needed.

2. A monitoring, updating, and maintenance capability confirming information integrity on an annual basis.

3. User friendly, prompt oriented, data entry and retrieval system accessible to the user community.

With the use of high speed, large storage digital computers, the means are available to accomplish the above and in addition, provide the ability to generate long range planning models, based upon simulation and other operations research techniques. From these models, a pattern of organized responses to any set of circumstances can be formulated. Such crisis anticipation capability is far superior than "gut" reactions taken as remedial measures with little insight as the future impact of such decisions.

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Acquiring the Data

The basis of any viable information system is acquiring good data. In most cases, this activity is the most time consuming, labor intensive, least glorious, and yet, most important activity of the entire systems structure. Figure 2 helps put this in perspective, as data acquisition is related to a total information system. This illustration also emphasizes what might be considered as axiomatic; new capabilities generate new requirements. Forest based information systems are no exception. The system, especially at the point of data acquisition, is in a constant state of flux, precluding the luxury of settling down to a prescribed routine. The system must perform and respond to these new requirements.

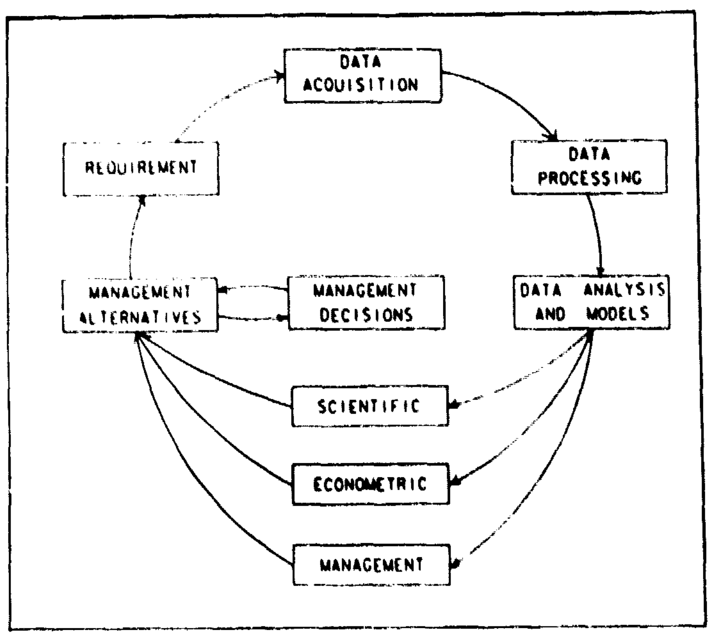

Figure 2 - The Dynamics of an Information System

Traditionally, data were collected by field crews of one or two people. Sample points were distributed systematically throughout the forest from which the data were secured. Such activity was periodic, and the data recorded ranged from simple tabulations on the "back of an envelope" to precisely tallied data collected from permanently monumented sample locations. With the advent of practical computer technology, inventory became a continuous activity with the quantity and quality requirements significantly increased beyond that of just a few years ago. Cruising timber (data collecting in the field) is hot, monotonous work. To keep personnel with the background necessary to collect data at the precision levels required, is difficult at best and the situation is getting worse. There are simply more attractive job alternatives in less hostile environments that offer equal or greater compensation.

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Assuming this problem were overcome through the normal economic mechanisms of supply and demand, it is seriously questioned whether or not traditional data collection procedures would be able to keep pace with the data processing and analysis capabilites anticipated for the future. The availability of well organized and compatible prior knowledge can have a significant and possibly decisive impact in ameliorating this data acquisition problem.

1.4 PROJECT GOAL AND OBJECTIVE

The goal of the FRIS Project was to thoroughly demonstrate the feasibility of utilizing Landsat multi-spectral scanner (MSS) data as a viable contributor to an operational forest resource information system, both in terms of technological capability and economic constraints of operations.

Such a digital data source must pass the test of compatibility and integration with existing data bases and information. The results of the demonstration would lead to a decision by St. Regis management as to the desirability of implementing this technology as part of an in-house independently controlled forest resource information system.

In support of this project goal, the following objectives were defined; albeit modified somewhat during the course of the project.

Land and Timber Stratification

To stratify land and timber to at least a Level I with computer aided analysis techniques. As time permitted to extend the stratifications into a Level II category as described below, as modified from Anderson, et al.(1).

LEVEL I AND LEVEL II CLASSIFICATION FOR FOREST COVER TYPE	
LEVEL I	LEVEL II
CONIFER (PINE)	CONIFER (PINE) HEAVY LIGHT CONIFER (CYPRESS) HEAVY LIGHT
MIXED CONIFER/HARDWOOD AND HARDWOOD	MIXED CONIFER/HARDWOOD HARDWOOD UNDERSTOCKED/NON-STOCKED BRUSH
NON-STOCKED WATER BODIES	NON-STOCKED-CLEAN WATER BODIES WET DRY

Landsat/Aerial Photographic Correlation

To empirically correlate Landsat classifications as derived through pattern recognition techniques to corresponding photo interpretive values as represented by cover type maps derived from aerial photographs. To demonstrate and document the predictability and repeatability of these results.

Geographic Referencing and Annotation

To apply techniques to permit automated geographic referencing of Landsat data to maps allowing for the overlay of political, ownership or survey boundaries as well as other irregular land and administrative subdivisions, and descriptive attributes.

Change Detection

To implement change detection techniques to monitor and update broad area information on owned and controlled lands by highlighting significant silvicultural and land use activity. Such a capability is predicated on accurate Landsat to Landsat scene registration.

Integrating the New Technology

To integrate the newly developed technology with existing operational information systems. To provide an independently fully retrievable current forest resource information system, compatible with ongoing projective planning models.

The FRIS project was designed as a three year project, to be done in four phases. These phases provide the outline for the remainder of this report and are as follows:

I. Project Start (Methods - 3 Months). In this phase, primarily housekeeping chores were accomplished. This included the three organizations; NASA, LARS, and STR, establishing management guidelines for the project, assigning personnel, establishing budgets, and gathering together all necessary information and material to proceed.

II. Demonstration (Results - 15 Months). In this phase both the technology and economics of implementation would be explored in light of the first four objectives as were stated above. The results provided as a product, a preliminary system design which formed the basis for the go-no-go decision for Phase III.

III. Systems Transfer (Integration - 15 Months). Encompassing the last objective, Phase III represented the integration of the technology into an operational production oriented system from a basically academic research environment. In this phase, the preliminary system design was finalized, vendors solicited and hardware/software installed.

IV. Implementation (Production - 3 Months). Primarily a documentation phase putting into St. Regis hands all those products necessary for independent operations. During this time, NASA and LARS phased out their activity and St. Regis took on full responsibility for operational implementation.

2.0 PHASE I - METHODS

2.1 PURPOSE

The purpose of Phase I was to accomplish the necessary preliminary activity and establish the overall ground rules under which the FRIS project would operate. This included identifying basic milestones for each phase of the project and establishing the general task timelines for each.

2.2 APPROACH

Although designed as a four-phased project, only Phase I and II could be addressed with any assurance, since much of the territory to be investigated in terms of system design, were still unknown. Even though Phase I planning addressed the entire project, emphasis was really placed on the Phase II demonstration. The degree of success of this activity would determine St. Regis' decision whether or not to pursue the project on to implementation (Phase IV).

Phase I activity was logically divided into five major areas of activity. These were:

1. Project organization
2. Test site selection and data acquisition
3. Gathering and preparation of data base source materials
4. Definition of benchmark evaluation techniques
5. Training development and scheduling.

2.21 Project Organization

The FRIS project started on October 1, 1977 and was organized under a project manager into four major sections as illustrated in Figure 3.

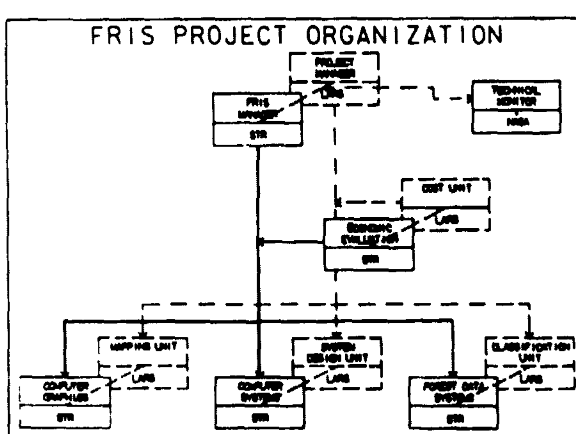

Figure 3 - St. Regis/LARS Organizational Structure for FRIS

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Each section had a LARS counterpart and functioned as outlined below.

. Interactive Mapping - Reviewed the existing mapping and computer driven interactive mapping systems meeting the overall FRIS requirement, focused on the data input needs for such a system and the image to map to image interfacing problems.

. Computer Systems - Established the hardware/software configuration and options available to meet operational needs in both image processing and computer graphics.

. Forest Resource Data - Two major functions were involved here; imagery and field data support (inventory). This section analyzed and evaluated image processing results over the prescribed sites and established a photo-to-ground double sampling procedure.

. Economic Evaluation - This section was to provide the cost consciousness of the project. It weighed alternatives and articulated the guidelines within which FRIS must operate.

The FRIS project phases were to be completed within the three year time frame of the project. To keep the total project in perspective and to highlight the timing of the major tasks within each phase, a project timeline chart was prepared during Phase I and it is illustrated in Figure 4.

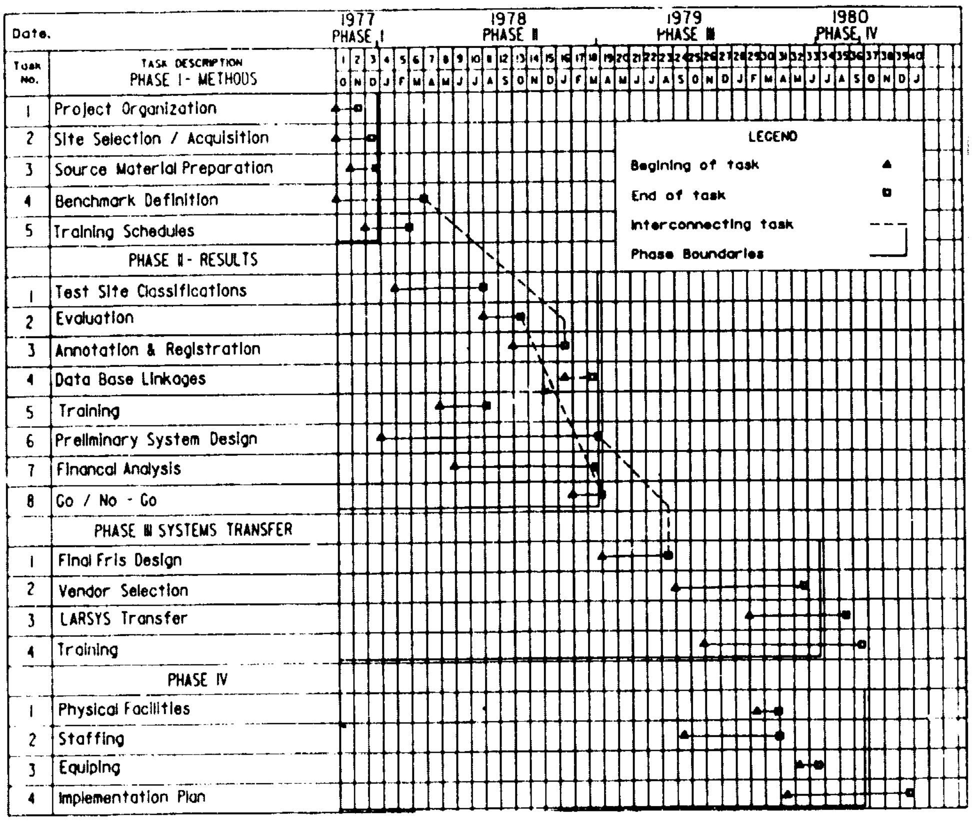

Figure 4 - FRIS Project Timeline of Activity by Phases

2.22 Test Site Selection and Data Acquisition

The geographic location for this project was the Southeastern United States, where St. Regis owns or controls some 924.3 thousand hectares (2.3 million acres) in the states of Texas, Louisiana, Mississippi, Alabama, Georgia and Florida; Table 1. From this area, four test sites were selected as being representative of the range of physiographical and climatic conditions found in the area. The test sites superimposed upon the divisional ownership map, is illustrated in Figure 5.

Table 1 - Southern Timberlands Division - Hectares (Acres) by Type Holding, Region and State

STATE	OWNED		CONTROLLED		TOTAL	
	JACKSONVILLE FLORIDA REGION					
Alabama			289	(715)	289	(715)
Florida	52,785	(130,380)	63,414	(156,633)	116,200	(287,013)
Georgia	27,587	(68,142)	150,185	(370,958)	177,773	(439,100)
TOTAL REGION	80,372	(198,522)	213,889	(528,306)	294,262	(726,828)
	PENSACOLA FLORIDA REGION					
Alabama	39,146	(96,591)	66,747	(164,864)	105,893	(261,555)
Florida	105,182	(259,799)	31,967	(78,958)	137,146	(338,751)
TOTAL REGION	144,328	(356,490)	98,714	(243,822)	243,039	(600,306)
	MISSISSIPPI REGION					
Louisiana	1,538	(3,799)	3,433	(8,480)	4,971	(12,279)
Mississippi	80,920	(199,873)	71,700	(177,000)	152,580	(376,873)
TOTAL REGION	82,458	(203,672)	75,093	(185,480)	157,551	(389,152)
	TEXAS REGION					
TOTAL REGION	229,485	(566,827)		-0-	229,485	(566,827)
TOTAL DIVISION	536,644	(1,325,571)	387,693	(957,602)	924,337	(2,283,112)

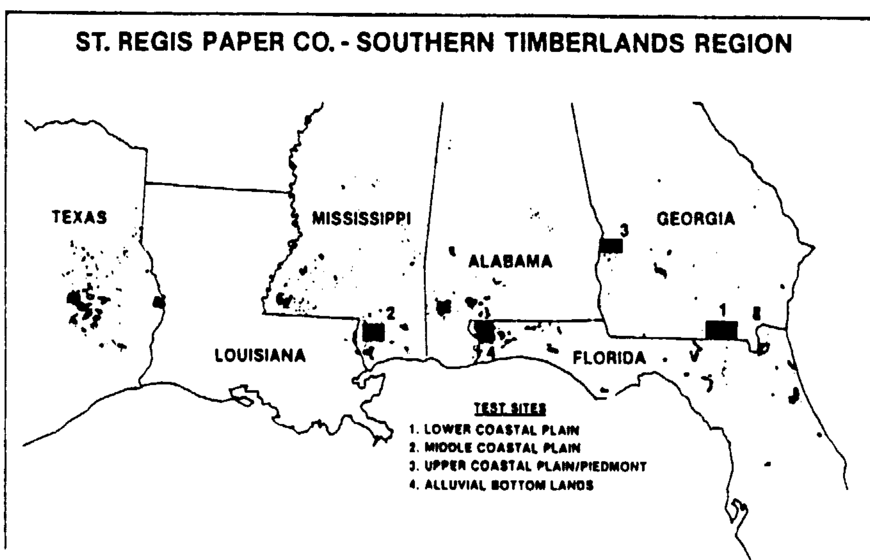

Figure 5 - St. Regis Southern Timberlands Ownership Pattern With FRIS Test Sites Superimposed.

A brief description of the test sites follow:

1. Lower coastal plain: This area of slight relief is locally referred to as the "flatwoods." Because of slight relief, it would appear the flatwoods represent a highly uniform and predictable physiographical situation. The appearance is deceiving for ever-present is a subterranean organic hardpan that varies both in depth and permability causing soil/moisture relationship variations that create wide fluctuations in forest productivity. From a remote sensing standpoint, the flatwoods are uniformly flat and coniferous with deciduous hardwoods and cypress occurring in distinct, well defined features called ponds and bays, pockmarked throughout the area. Hardwoods and cypress also occur along the major waterways and minor subdrainage systems throughout the area. Because of the general uniformity of the area, the lower coastal plain was thought to represent the area with the highest possibility of success. The test area in this province is located close to the community of Fargo in southeastern Georgia and consists of some 38,462 ha (95,000 ac).

2. Middle coastal plain: This area is characterized as gently rolling in terrain. The middle coastal plain falls in a broad area between the upper coastal plain/piedmont and the lower coastal plain. The test area for this province was in southeastern Mississippi near Slidell, Louisiana and encompasses some 28,340 ha (70,000 ac).

3. Upper coastal plain/piedmont: This area is rugged and highly dissected. This physiographic province represents the closest thing to mountainous terrain found in the project's focus area, and is indeed the transition zone between the coastal plain and the Appalachian mountains. Ranges in relief are wide as are the potentials for forest productivity. This general area was considered as the greatest challenge for the FRIS classification technology. The test area of approximately 24,291 ha (60,000 ac) is located in west central Georgia near the city of Columbus.

4. Alluvial River Bottom - These areas are called subprovinces since they occur throughout all the other provinces. In general, alluvial bottoms represent the major drainage system of the area. The primary commercial hardwoods occur in the bottomlands as well as the largest areas of mixed conifer-deciduous association. This test area was added as an after thought and was to be addressed during the project only if time permitted. The alluvial test area was located in the Florida panhandle near Pensacola and constitutes some 32,388 ha (80,000 ac) of the Escambia and Yellow River drainage systems.

Once the test sites were identified and located geographically, the data acquisition process was begun. Working closely with the LARS staff, the optimum season of coverage was determined and a search request of Landsat data made to the Goddard Space Flight Center (GSFC). Representatives from LARS and STR reviewed the data quality, selected appropriate scenes and

ordered the computer compatible tapes (CCT's). The scenes ordered are identified in Table 2.

Table 2 - A List of Landsat Data According to Date and FRIS Test Site

TEST SITE	DATE	SCENE ID
I Fargo, GA	30, Dec. '76	2708-15090
	17, Apr. '77	2816-15042
II Slidell, LA	17, Dec. '76	2695-15381
	28, May '77	2857-15305
III Columbus, GA	21, Oct. '76	2638-15225
	7, May '77	2836-15141
IV Pensacola, FL	22, Oct. '76	2639-15283

It will be noted in three of the four areas, both fall/winter and spring/summer data were secured. (No spring data of good quality were available for the Pensacola site.) It was important to assess by site, the season most likely to yield best classification results and if the improvement was great enough to rule out the other season. Previous experience at LARS indicated higher success with spring or summer data, while winter data would be more amenable for an operational FRIS since this season would coincide with the annual updating cycle; January 1 - March 31.

An order was placed with GSFC in late October for the data listed in Table 2, and the first CCT's were received by LARS in mid-November. These data were reformatted and corrected by LARS in preparation for the demonstration phase of the project.

Because of the relatively short duration of Phase II; 15 months, and the boundary overlay difficulities at LARS, it was decided to select one prime test area which would include annotation, and to use the other sites to demonstrate the repeatability of classification capability. The flatwoods test site near Fargo, Georgia was selected as the prime test site. Since it was to be the only one annotated with administrative unit and operating area boundaries, it also became the principal FRIS demonstration site.

2.23 Gathering and Preparation of Source Materials for Data Bases

For the purposes of this report, a data base is defined as any body of data in similar format that provides the basis for information extraction. Any system including FRIS, can be and usually is, made up of multiple data bases. The responsiveness of the system is directly related to how well the data bases are linked together.

Within St. Regis, Southern Timberlands, the very first organized division-wide inventory attempt, dates back to the early 1950's. Coincident

with the emerging electronic data processing technolgy (unit record equipment), this inventory was called Continuous Forest Invento / (CFI), and was rapidly embraced by large segments of both public and private forestry. The sampling scheme was one of permanently relocatable sample plots of fixed dimensions. The sample design was systematic with very low intensity. The object of this sampling procedure was to provide repeat measurements on individual tree and forest stand parameters. From these data, growth estimates could be derived either empirically, or over time, through regression techniques. Because of the repeat nature of the measurements, a reliable body of data was amassed pertaining to natural mortality rates and the nature of the young growth restocking the forest.

In terms of describing the forest dynamics through the observation of overall change, CFI accomplished what it was supposed to; but because of such a light sample, the results held only for general forest-wide situations. In providing basic timber volumes, frequency and overall stand conditions for the pertinent forest subdivisions, CFI was totally inappropriate.

St. Regis, in 1964, dropped the CFI label in favor of Permanent Growth Sample (PGS), to dispell any illusions of meaningful detailed inventory from this system. To meet the very pressing need for a unified inventory for long range planning purposes, the Southern Timberlands Division installed and revised over a seven year span, an in-place inventory designed specifically to: address volume and frequency quantities, describe and qualify the various forest conditions, and map the geographical distribution of the defined timber stands. Called Operating Area Inventory (OAI) after its prime unit, the inventory has been in place over ten years and has been enhanced to include an annual updating procedure (Update). All three systems are computer based, providing an organized alphanumeric attribute data base. In terms of data definition and structure PGS, OAI and Update are compatible.

Operating Area Inventory consists of three primary sources of data and information: imagery (photographs), graphics (maps), and tabular attribute data (inventory). Although highly labor intensive, graphics were the vehicle that attempted to link the imagery and the tabular inventory together through a geographic referencing scheme; the map. This was accomplished through four steps:

1. Annotation of property boundaries and primary cover types onto current aerial photography prior to the inventory.

2. Using the annotated photographs as a guide, design and execute the ground sampling procedures constituting the inventory.

3. Capture and draft basic property and planimetric information from the best source possible including known surveys and U.S. Geological Survey topographic quadrangle maps. Where possible, these are done from 7.5 minute sheets.

4. Cover type overlay maps prepared by the inventory crew from photo interpretation and containing the pertinent attributes from inventory, are integrated into the map base. Figure 6 shows the general detail of the overlay maps. Since the cover type boundaries are taken

directly from the photograph, there are inconsistencies of scale. In any roll of aerial film, individual frames will vary from the targeted scale to the degree the aircraft fluctuates in its position relative to altitude. Although not always done in the past, these variations should be reconciled when drafted and before area determinations have been made.

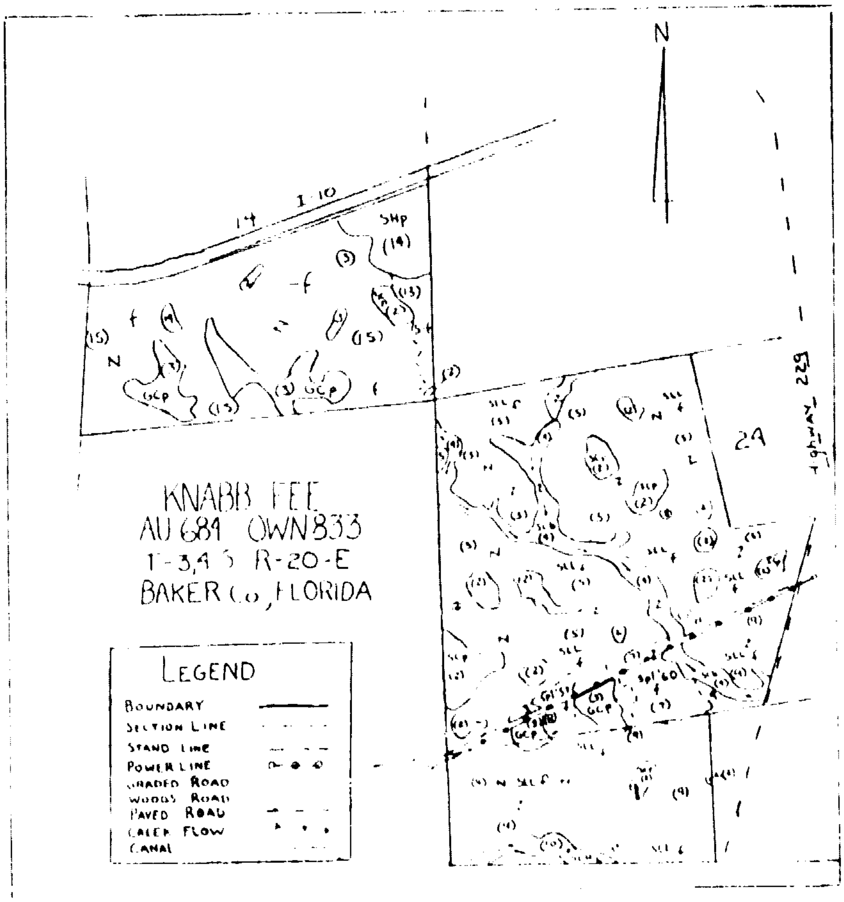

Figure 6 - Administrative Unit Overlay Map Depicting Forest Cover Types with Associated Attributes

For every test site, a complete set of current data and information was provided to use as a reference for FRIS performance and as the basis for annotation and image interpretation. It should be pointed out that the current information base, including new color infrared ph... graphy, inventory and Administrative Unit maps had all been compile... m data gathered within a year of the Project's start. Aerial photogr... ainable on demand from any one of several vendors; however, the e... an in-place, computer based inventory system with supporting con... raphics is not, and they provided the key ground support data ... viable information system. Without these two data bases alread... place as an information source, it is doubtful that FRIS could have been proposed in the context it was.

Aerial photographs and inventory provided support to the various classifications tasks, while the maps provided the basic data for boundary control

and annotation. Included as a separate channel of data along with the digital image data from Landsat, boundaries provided the spatial control on the Landsat scene. With this control, area summaries by classified feature group were possible.

For the purposes of the Phase II demonstration, LARS, with St. Regis' help, created a digital data base consisting of Administrative Unit (AU) and Operating Area (OA) boundaries as a minimum level of control. An AU is defined as a base unit of administration of 400 ha (1,000 ac.) or larger. They are easily recognizable on the ground because they are bounded in general, by relatively stable cultural or physical features such as roads, powerlines, and rivers. Each AU consists of a whole number of Operating Areas. Operating Areas are timber stands with size restrictions. They exhibit the following attributes:

> Uniformity of species composition, i.e., pure pine (conifer) or hardwood (deciduous/cypress) occupies 75 percent or more of the arboreal crown canopy[1]; mixed pine-hardwood, where pine or hardwood/cypress make up less than 75 percent but more than 25 percent of the timber crown canopy. Those timber stands whose sum total crown area makes up a canopy covering less than 25 percent of the total available area, are generally considered as understocked. These criteria refer to those timber species dominating the growing site. In addition, OA's are differentiated between natural and artificially regenerated (planted), and merchantable or premerchantable in size. Merchantable being here defined as those timber stands in which one third or more of the stems are 12.7 cm (5.0 inches) DBH (diameter breast high) defined as 1.37 meters (4.5 feet) from ground level. These trees have attained a height of about 9 m (30 feet) average, and exhibit well defined crowns in healthy stands.
>
> Premerchantable stands, especially those classed as seedlings with diameters less than 1.27 cm (.5 in.) DBH do not necessarily fit into the cover type criteria above; for example, a plantation of pine, successfully regenerated, may not exhibit any significant crown closure before age eight to ten years. In fact, a stand under five years old may have trees with no real structured crown at all. As a result, there may be no canopy as such, and yet the stand may be fully stocked and pure pine.
>
> The yearly profile of a developing forest must be understood before a fair test of classification accuracy can be attempted. The analogy to other agricultural crops is a matter of time scale; the week to week development of an annual crop versus the year to year development of a producing forest.
>
> Large enough to be considered a viable entity - 16 ha (40 ac.) or so, and yet small enough to allow complete operations in one year (harvest, site prepare or plant). An OA need not be contiguous, but can be made up of components as small as the minimum mapping unit; some 1 ha (2.5 ac.).

[1]Crown refers to the organized limb, twig and leaf structure of a tree. Canopy is the sum total of tree crown area within a defined association, viz., timber stand.

- It must exhibit the same relative productive capacity throughout, since the OA is the prime unit for projection.

- The same basic silvicultural prescription should be applicable to the entire OA.

Since the OA is the prime unit for inventory, projection and thus management, it is essential to maintain control at that level. Figure 7 illustrates a completed Administrative Unit Map with its component Operating Areas.

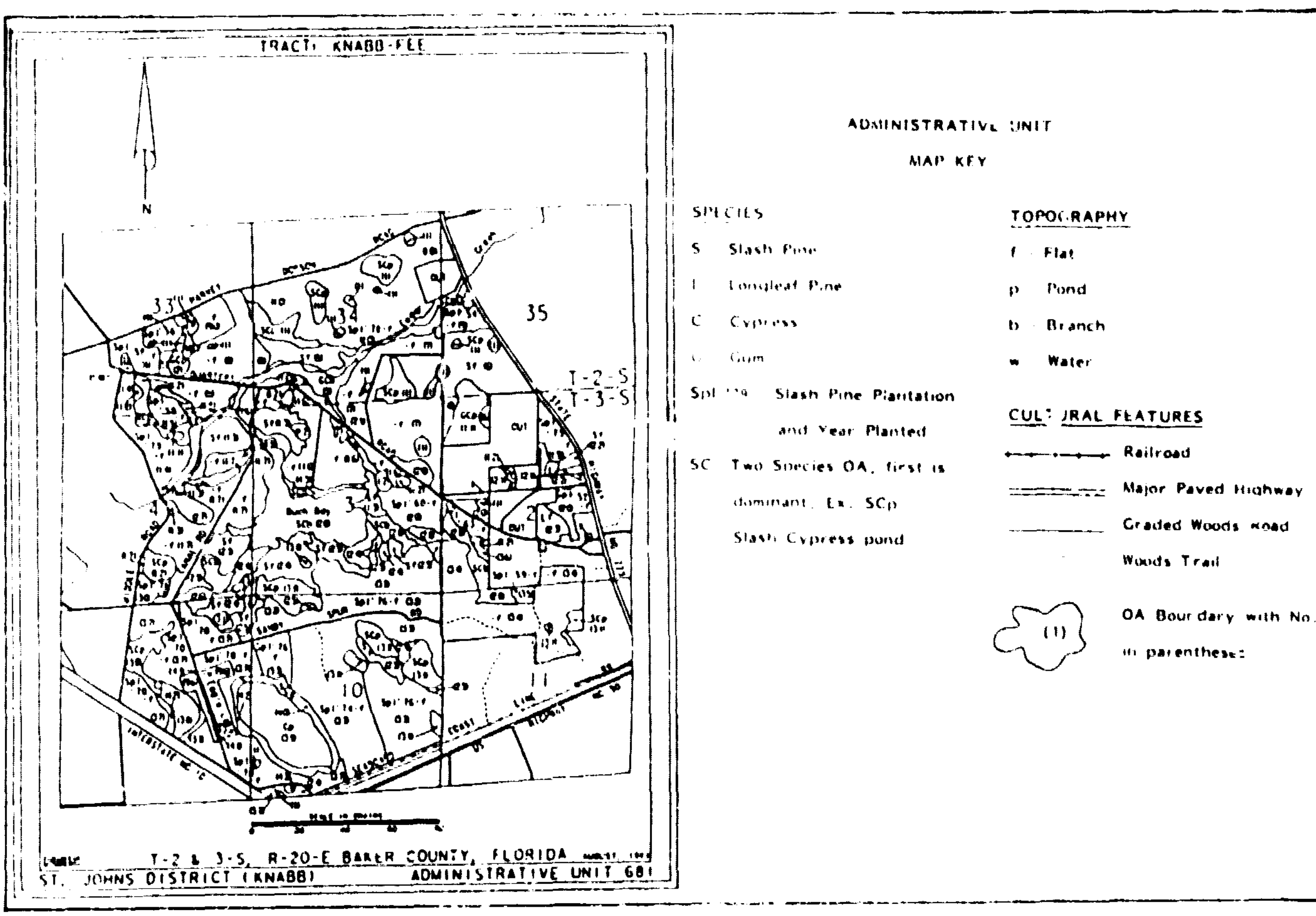

Figure 7 - Standard St. Regis Administrative Unit Map

To digitize into a data base all the detail shown on the AU map would be excessively time consuming and to do it on all test sites utilizing the technology then existing at LARS would extend the length of this project far beyond the time allocated for Phase II. To successfully demonstrate the procedure within the time constraints, just the AU's and OA's would be digitized for the project with the details of a comprehensive cartographic data base being left for St. Regis operational considerations.

2.24 Benchmark Evaluation Techniques

Although it was realized some form of accuracy assessment would be required to evaluate the FRIS efficiency, precise methodology was not at all obvious during the Phase I activity. While the FRIS project recognized the mapping function as the basis for geographical referencing and the inventory as the repository for basic land cover attributes, it was primarily concerned with digital image processing and the links by which this technology could be integrated into an ongoing operational system. With both the mapping and inventory function, historical data exists against which innovations and change can be measured. This was not true with digital imagery. Except for aerial photography, the product of which is considerably different than a digital image, there was no real feel on how successful classification results would be in a forest based environment. Because of the heterogeneity of the actual cover as seen from above, it was seriously doubted if traditional test field procedures as done in agriculture would suffice. These procedures, however, have been in use, are well documented and accepted in the existing renewable resource user community. With this in mind, it was decided to implement these procedures at the outset and to evaluate their utility once results were in hand. As far as setting predetermined levels of precision or "accuracy", it was decided that this might unfairly restrict the acceptance parameters beyond that which was reasonable.

In addition to the evaluation of technological performance, an important if not overriding consideration in management's final approval of the concept, was that of costs, or economic evaluation. Again, historical data exists on the costs of inventory, mapping and aerial photography. The accrued benefits from Landsat data had not been demonstrated and were more conjecture than fact. Conjecture or not, they were based upon past experience in other areas of renewable resources, and served well as an initial hypothesis. The hypothesis would be tested by the demonstration, at least to the point of establishing a level of performance. When added to what was known from mapping and inventory, an overall economic picture of FRIS emerged as a replacement to the existing information system. To be realistic, any economic analysis had to be made within an operational production environment and put into terms meaningful to St. Regis. As such, while LARS supplied technical support, the lead had to be assumed by the St. Regis FRIS staff.

2.25 Training Development and Scheduling

The training emphasis in Phase I was placed on defining and scheduling the training to be done during Phase II. From the outset, it became apparent that the St. Regis component of the project would have to play active roles in the demonstration if it were to be successful. Because of this, it was essential to transfer the remote sensing technology to the FRIS staff.

This transfer was also important if, by the end of the project, St. Regis personnel were to have the capability of independently operating the system.

Technology transfer in the sense it is presented in this report, entails both the information dissemination function, and the technical transfer of systems and information to the potential user, St. Regis. This activity would take on several forms:

. Formal (lecture/workshop) presentation

. Hands-on training sessions

. Formal reports and project review

. Personnel interactions

. Symposia and seminars.

The following lists the sequence of training activity planned for Phase II. The sequence was to be repeated more than once during the demonstration and augmented by a computer terminal linking LARS, St. Regis, Jacksonville and St. Regis, Dallas; the St. Regis mainframe computer.

FRIS Technology Transfer Activities - Phase II

. 2.5 day lecture/workshop on the fundamentals of remote sensing and machine assisted analysis in Jacksonville.

. Hands on classification training at LARS; 2 two-week sessions.

. Project review of benchmarks and classification procedure; 2 days at LARS.

. Advanced lectures/workshops in FRIS procedures; 3 days at LARS.

. Hands-on training; 2 two week periods in Jacksonville.

. Project reviews for evaluation of results and recommendations.

3.0 PHASE II - DEMONSTRATION

3.1 PURPOSE

This fifteen month phase was designed to test existing image processing techniques in forestry applications, and to report on the technical and economic results of this demonstration with regards to the practical applicability of the concept in light of St. Regis' operational objectives.

3.2 RESULTS

As is often the case in research of any kind, the perceived issues and approaches soon give way to a shift in emphasis brought about by factors not readily obvious at the outset. FRIS was no exception, and the transformation began almost from the beginning. Because of the scattered pattern of land holdings within St. Regis control and typical of private land ownerships in the South, geographic referencing soon became an issue of primary importance to the entire FRIS project. Rather than ancillary, the map became the very centerpiece of FRIS and was the base to which all other data were to be referenced (Landsat imagery and inventory). To be effective, the mapping function had to be automated and computer driven; a notion almost as foreign to the principals as digital imagery itself. In addition to image processing, computer aided cartographic techniques had to be demonstrated along with the linkages to tie together the three digital data bases. Successful completion of these demonstrations would satisfy the first four major objectives of the Project; land and timber stratification, Landsat/aerial photographic correlation, geographic referencing and annotation, and change detection. Integrating the new technology will be the subject of Phase III, Systems Transfer; however, a preliminary system design was proposed as part of Phase II providing the basis for the decision to proceed (Go/No-Go) and to establishing a point of departure into Phase III.

Finally, a financial evaluation of FRIS vs. the current system was made. This looked at FRIS in light of the current system, weighted comparable operational costs and gains and defined auditable areas upon which performance could be measured.

3.21 Image Processing System

For the purpose of demonstration and baseline evaluation, image processing techniques and software developed by LARS over the years was used as is, in the Public Domain (COSMIC) or under development (LARSYS, LARSYSDV). While it was recognized that this basic image processing system was developed over many years in a research/teaching environment, thorough assessment was required to determine just what to keep or discard. Basically, two major activities were involved: pre-processing and classification.

3.211 Preprocessing

Not well understood at the outset, the mysteries of preprocessing soon unfolded and revealed a terribly time consuming and labor intensive activity totally incompatible with production operations. So involved and complicated was this activity, it totally precluded including the fourth test site (Escambia River Bottomland) within the Phase II timeframe.

The preprocessing activities included the five following tasks:

- Reformatting - the least of the preprocessing problems, reformatting merely transforms the Landsat data tape format as received, to a format compatible with LARSYS.

- Geometric Correction - a general image orientation in terms of rotation to north and south and de-skewing caused the Earth's rotation as the scene is developed.

- Precision Registration - the registration or overlay of the Landsat image to a map based upon ground control information. This is usually digitized map coordinates. Corresponding control points must be located on both the image and the map. A mathematical model describes the transformation between coordinate systems, and a least squares approximation is used to establish the best fit.

- Image Registration - The registration or overlay of one Landsat image to another image of the same area taken at a different time; season or anniversary.

- Boundary Definition - The nature of the St. Regis ownership patterns dictates prior boundary overlay is essential if Landsat data are to be considered as an important data source.

All the processes herein described and utilized by LARS at that time, worked satisfactorily. However, as an operational system, they were totally unacceptable, because of the excessive time required and highly labor intensive nature of the procedures.

Conceptually it was seen that there was no reason the preprocessing chore could not be reduced to a totally manageable situation if not a transparent one. For initial operation this was to be resolved in Phase III and reported as part of the systems transfer. Some of the factors leading to this optimism in Phase II included:

1. Addition of a color image display unit providing interactive capability.

2. Computer mapping technology.

3. The provision by NASA of a geometrically corrected product with a set of ground check point coordinates.

4. The definition of a standard FRIS data set. All input would be transformed to the standard and FRIS would generate the required data sets from the standard. This concept would provide the

flexibility to receive digital data from any source, a definite ultimate requirement of FRIS.

3.212 Classification

Classification is the ending process involved in transforming raw Landsat digital data into a coherent information base. Classifications were done on all the test sites (TS) previously defined, except TS-4, the Escambia River Bottomland. This was not due to any inherent problems other than the time constraints of the project and the unexpected time factor required to digitize the boundary data base. Because of this, the three sites remaining were really subsets of the original test sites described. The approximate areas of the sites were: TS-1, Fargo, Georgia 38,461 ha (95,000 ac), TS-2, Picayune, MS 8,825 ha (21,798 ac) and TS-3, Columbus, GA 2,248 ha (5,552 ac). The three tests sites provided the project with a spatial replica in triplicate. On the prime test site (TS-1) in the lower coastal plain, anniversary data (1976, 1977) were analyzed to provide a replicate in time. The spatial replicates would provide indication of the predictability of the procedure under widely differing situations. Temporal replication suggested that results were repeatable as described by Mroczynski (3). No claim is made here for definitive answers, but rather only strong indications suggested by the results. More work is needed to broaden the base of results and to substantiate or refute those made here.

To insure that only variations in test area location and not in approach would occur, a standard set of procedures were developed and followed. Figure 8 illustrates the flow of activity to be followed during the project for

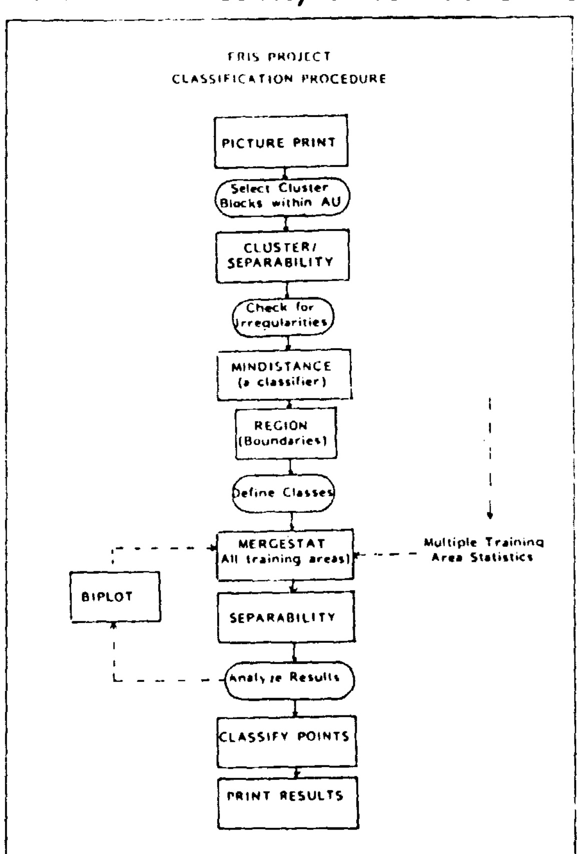

Figure 8 - FRIS Project Classification Procedure

classifying scenes. Certain LARSYS and LARSYSDV processes are noted (in capitals). A partial list and summary of key processors transferred will be found in Appendix A.

Training: Without a doubt, the single most critical operation in the entire image processing sequence, is the training of the classifier. In effect, this is no more than a set of decision rules for the computer to allocate the various reflective values into a predetermined, user defined number of feature groupings. Training must be done in such a way that it is all inclusive of the major features of interest, to avoid errors of omission. At the same time the training should not attempt to extend beyond the system's discriminatory properties, to avoid errors of commission.

Because of the broad base of St. Regis data already in hand in the form of photography, maps and inventory, it was felt the training task would be minimized. The training approach for FRIS can be considered as neither supervisor nor non-supervised within the context of those classical definitions. Rather, cluster blocks were selected, hopefully representing within each block, the range of class diversity existing within the subject area. Several (six or more) cluster blocks for each test area were selected and interpreted separately.

As was anticipated at the outset, difficulties arose almost immediately in the LARSYS approach from an operational standpoint. While others arose later and are to be considered in an operational FRIS, the initial problems had to be addressed just to allow the project to stay within its time constraints. From the initial PICTUREPRINT of the test area, it was most difficult to pick a training site meeting the basic criteria of diversity. The problem was one of general location, or simply finding the area of interest within a scene. The second, an extention of the first, was that of specific location or establishing the detailed position necessary for training purposes. It was very time consuming to register the training set to a map with any kind of confidence. Attempts were made to place the training field wholly within an Administrative Unit. In this we were generally successful, at least in TS-1 where the AU boundaries were graded sand roads offering high contrast. Within the training field, to define road intersections or stand (OA) boundaries was all but impossible. Figure 9 illustrates the problem. To alleviate the problem, the MINDISTANCE and REGION processors were added. Although these were two additional steps, it was well worth it in time taken to train and classify. Without them, this demonstration task might not have been done within the time constraints allocated and would shed serious light as to the economic viability of the entire operation. The MINDISTANCE processor, a simplified classifier, extends the cluster results out to include the entire AU. Since the cluster field was still rectangular, more than just the AU was included; Figure 10. REGION took the boundary data as digitized, and added those values as a channel of information to the classified Landsat results tape. Once that was done, all areas outside the boundary were dropped.

Because of the lack of a computer mapping capability, the Landsat clusters were expanded to be equivalent in scale to 1:15,840, the nominal map scale. In this way, the data could be directly overlayed on the map units, greatly facilitating training. While training became easier, reliability was impaired, and in fact, when considering the dummy pixels added to accomodate the expansion, confidence in the integrity of the training set suffered. From this point on,

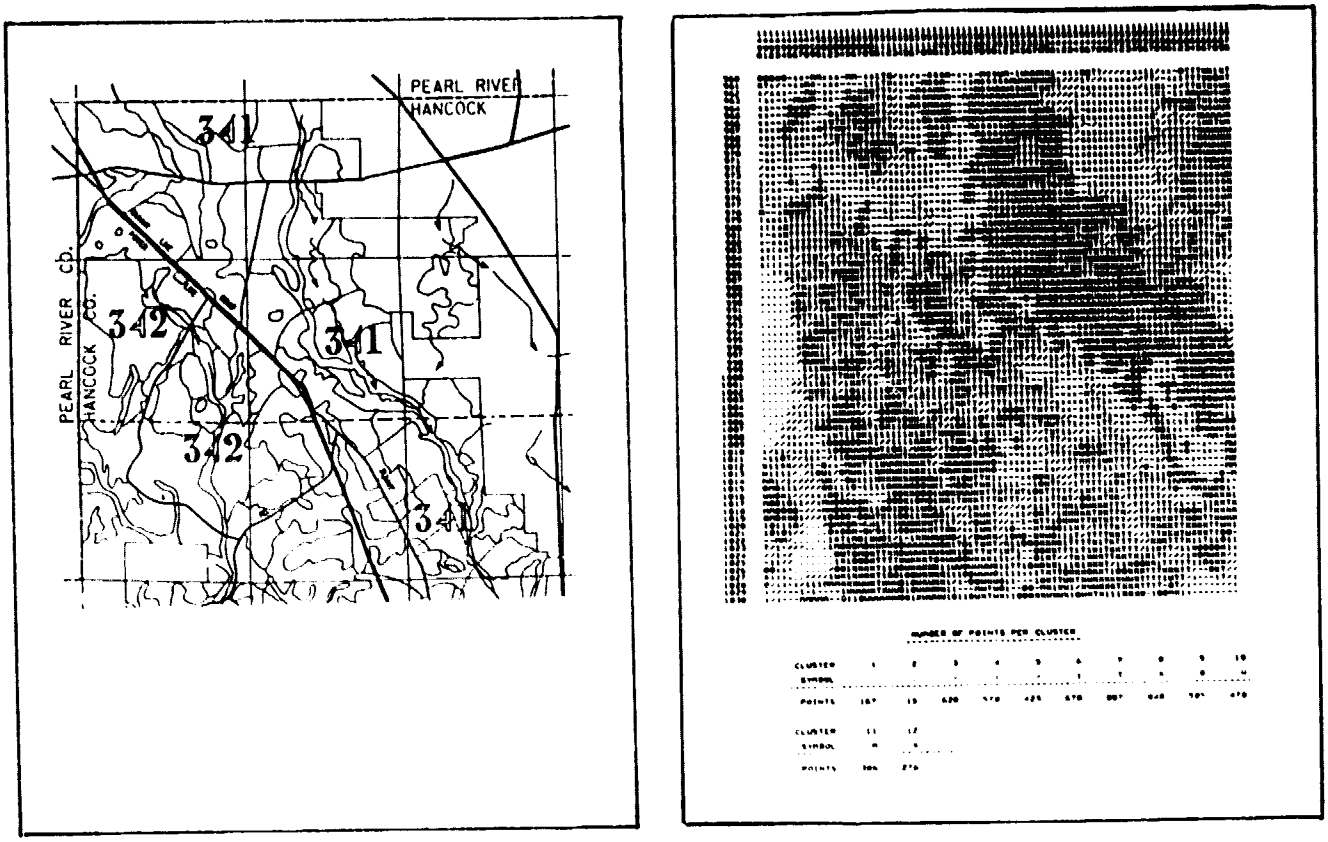

Figure 9 - Portion of AU Map and Associated Cluster Block

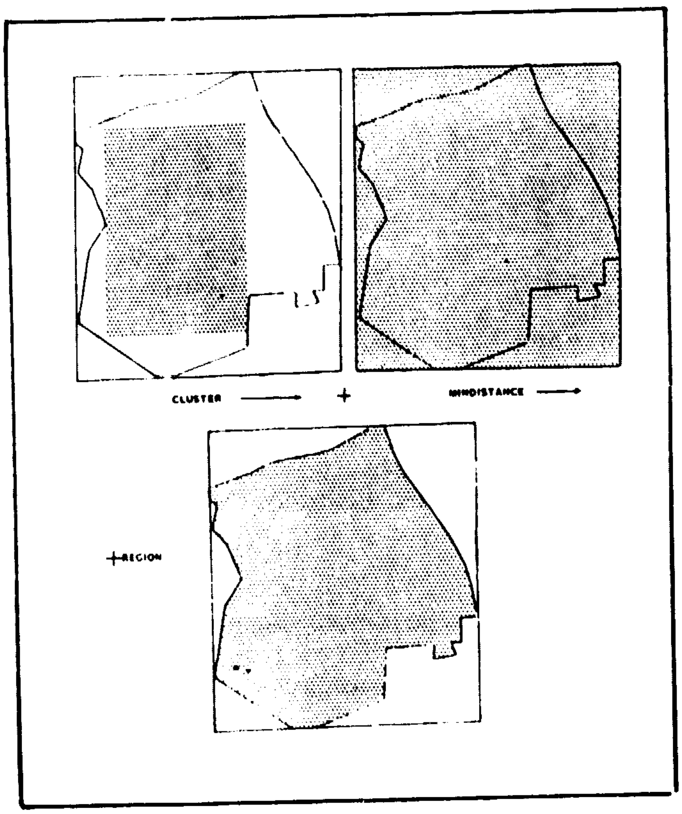

Figure 10 - Creation of Cluster with Irregular Boundaries

the original line printer scale was retained (1:24,000), and the maps were reduced accordingly by photographic means, and printed out on clear mylar. These transparent maps were then directly overlayed on the training set, which was now an AU with definable boundaries.

While this procedure was tedious, it was at least manageable. It became clear, however, software enhancements would be required to specifically establish a cluster algorithm allowing for irregular boundaries. Also, the addition of a computer graphics capability would have immeasurable impact on this whole process, a fact to be later substantiated. A procedural outline for the project, from training through classification, is included in Appendix B.

Classify: Image classifications were done on all tests sites as soon as the boundaries were digitized and basic feature training completed. The largest of the test sites was Test Site I near Fargo, Georgia. This site, some 38,500 ha (95,000 ac) included 29 Administrative Units. While classification was done on the entire site, four units were selected for detailed analysis. The overall results for these units did not vary significantly from the total, and the reduced area was far more manageable allowing more analysis to be done with the time allocated. The overall results along with those of the Picayune, Mississippi and Columbus, Georgia sites are included in Table 3.

Table 3 - Classification Results - Leaf Off Season (Oct-Dec). Three FRIS Test Sites as a Percent of Total Area

TEST SITE	St. Regis Inventory		Landsat Classification	
	PINE %	OTHER %	PINE %	OTHER %
1 - 38,461 Ha (95,000 ac) 12/76	55	45	55	45
12/77	55	45	53	47
2 - 8,825 Ha (21,800 ac) 12/76	74	26	53	47
3 - 3,717 Ha (9,200 ac) 10/77	60	40	56	44

3.213 Classification Results

The classification results shown and evaluation procedures that followed were exactly as prescribed by LARS based upon the software design and experience of the LARS staff. Only by proceeding in this way could a procedural assessment be made. As was expected, several modifications both structural and philosophical would have to be made before this image processing procedure could be considered operational; however, most all were astonished at how well the package performed in a real life situation.

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As could be seen in the results, extraordinary correspondence was exhibited between the inventory updated values (St. Regis) and the classification for TS 1. This seemed to hold true regardless of season as shown in the four unit subset tabulated in Table 4[1].

Table 4 - TS-1 Classification Comparison; Winter, Spring and Bi-Temporal Combination as a Percent of Total Area. AU 264, 267, 268, 271

Cover Type	Winter 1976		Spring 1977		Bi-Temporal	
	Percent	Diff.	Percent	Diff.	Percent	Diff.
Pine	55.5 (56.8)	-1.3	55.8 (56.8)	-1.0	55.4 (56.8)	-1.4
Mixed	41.9 (40.1)	+1.8	41.5 (40.1)	+1.4	39.0 (40.1)	-1.1
Other	2.6 (3.1)	- .5	2.7 (3.1)	- .4	5.6 (3.1)	+2.5

Bi-Temporal is the combining of both winter and spring data (four channels each) into one eight channel data set. In doing this, an attempt is made to capture the strong features of each season into a synergistic data set that neither season could provide singly. While it is not altogether obvious from Table 2 that this is the case, increased discrimination seems to be possible to a Level II as described later in this report.

In Table 5, a comparison is made between anniversary data on the same four unit subset.

Table 5 - Comparison of Anniversary Data Analysis (Winter). AU's 264, 267, 268, 271: TS-1

Cover Type	Winter 1976		Winter 1977	
	Percent	Diff.	Percent	Diff.
Pine	55.5 (56.8)	-1.3	56.9 (56.0)	+ .9
Mixed Pine/Hdwd	41.9 (40.1)	+1.8	43.1 (40.8)	+2.3
Other (nonstocked)	2.6 (3.1)	- .5	- (3.2)	-3.2

[1] In tables 4, 5, and 7 figures in parenthesis refer to the St. Regis updated inventory information.

Note in this table, not only the close correspondence between classification and updating, but that the results tend to hold from year to year. While one year one time seems hardly definitive, it is at least indicative of repeatability of results.

Although the areal extent of other (non-stocked) is small, it does represent the only significant departure from the overall correspondence between years and between inventory and classification. First of all, the difference in the inventory figures between dates is a function of updating adjustments. In the flatwoods environment, mixed pine-hardwood and hardwood timber stands tend to fall in wet areas (ponds, bays, creeks, etc.). Winter (leaf-off) reflective value for hardwood has very low response because of the water influence. It is noted in 1977, no area is classified as non-stocked. Records indicate that 1977 was a wet year in comparison to 1976. Free standing water is a typical condition of the land in wet years. The normal bright reflections experienced in cutover lands would be materially affected by standing water, to the point of being misclassified as hardwood swamp land. In this part of the country, soil/water relationships become an important addition to the training support used as input to the process.

Tables in themselves can be deceiving. Given enough area, nonsystematic errors tend to compensate, imparting a false sense of security in the results. The real test of positional accuracy is how well the classified entities correspond with ground features, or how those features are depicted on photographs and maps. Positional accuracy depends upon two things; registration and rectification. For the purposes of this discussion registration refers to the geometric alignment of two or more digital data sets such that the area of resolution on the ground represented in each set, can be automatically superimposed. Rectification refers to the geographic alignment of a digital image, map or photograph to an actual ground location. Clearly, if classification results are being compared to maps or photographs, and these two media are not rectified as well to ground positions as the Landsat data, the positional errors are not that of the digital imagery but of the reference base being used. Since the maps are generally drafted from current photographs, these two products register well, but have similar rectification errors, directly related to the variation in photographic scale.

Finally, it should be recognized that a map provides only a generalized basis for comparison. As a working tool, the AU map as now used, must generally represent the ground conditions, but not be so specific as to make the map busy beyond manageability. As an example, in the lower coastal plain such as TS-1, many small wet areas or ponds may be aggregated into one operating area. These ponds may contain cypress, hardwood or slash pine singly or in combination. As an aggregate, the OA may be called a slash pine/hardwood or slash pine/cypress pond. Landsat, of course, doesn't know this and classification will depict what is detected by the sensors.

As defined earlier, Level II classifications are those which build on Level I classifications, e.g., broad species groups, and further subdivisions

by density (crown closure) within a specific group. The combining of seasons in a bi-temporal data set tends to improve the chances of success in doing this. In Administrative Unit 264, TS-1, lightly stocked seeded pine separated successfully from older, denser pine plantations; Table 6.

Table 6 - Level I and Level II Summaries by Percent of Total Area
AU 264 - Bi-Temporal Data Set

Type	Level I		Type	Level II	
	Landsat	Updating		Landsat	Updating
Pine	57.9	59.5	Planted Pine	32.5	31.7
Mixed	36.2	38.0	Seeded Pine	25.4	27.8
Other	6.0	2.5	Mixed	36.2	38.0
			Other	6.0	2.5

Figure 11 dramatically shows this stratification capability and also illustrates the registration, rectification and generalization problems mentioned above. The following points are offered with regards to Figure 11:

1. The map; Figure 11-A, is a portion of a standard AU map with cover type attributes missing. Note all the ponds and bays (irregular polygons within the scene) north of the road designated B-5, are in Operating Area #4. These wet areas are called slash pine/cypress type.

   The permanent dotted line, left of center, represents a break in cover type, not topography. The OA on the right (east), #6, is a seeded area, that was direct seeded by aircraft. To the west; OA #11, is planted slash pine.

2. When the classification, Figure 11-B is overlayed on A, Figure 11-C results. Note many of the ponds don't quite match the expected symbol distribution. Much of this is due to the scale problem mentioned earlier. However, notice the light pine symbol showing up in the big dominant bay in the center of the scene right under the 6 and 4 of the AU number. This is a significant island of pine not recognized on the map. This plus several smaller ponds with the heavier pine symbols throughout, demonstrate the problem with using generalized maps for the analysis evaluation.

3. Generally, the positional accuracy seems to be at least commensurate with the tabular agreement values, with probably more error being detected in the map rectification than in the Landsat to map registration.

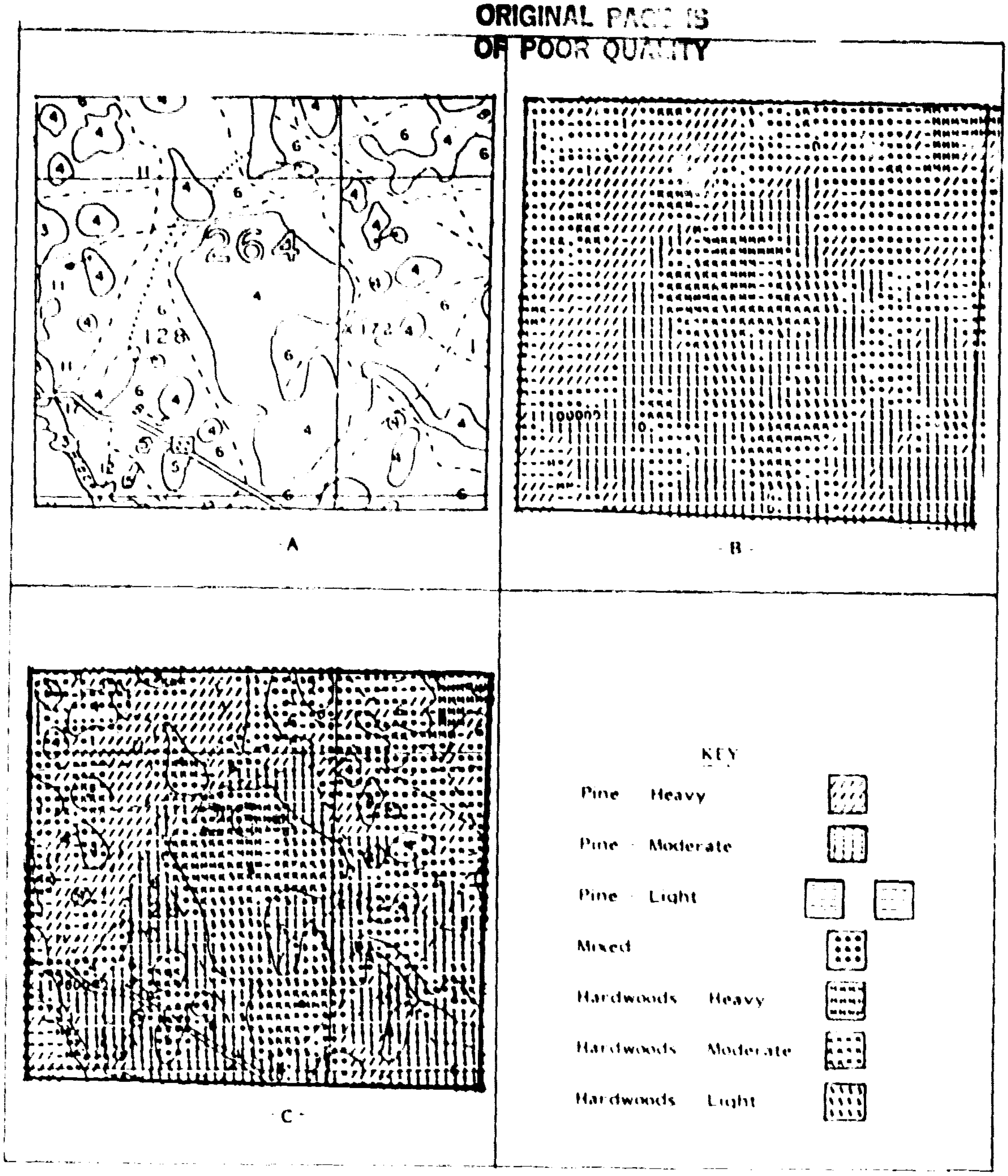

Figure 11 - Landsat to Map Registration (Manual)

Discussion

Similar positional accuracy results were found on TS-2 and TS-3 and although not analyzed to the extent of TS-1, substantiate the notion that within the southeastern United States, classification performance in forestry related activity is predictable; that is, similar levels of precision can be expected throughout the range of conditions existing within the region. To reach this conclusion in the face of the tabular results shown in Table 3 required learning a bit more of the nature of Landsat multi-spectral data. This can be summed up in the following remarks and illustrations.

1. On single date, non-ratioed digital image data, rengenerated pine less than four years old cannot be separated from the surrounding ground clutter. On the Picayune tests site; TS-2, where the greatest difference between Landsat and the updated inventory occurred, substantial areas of pine were in OA's less than 4 years old. Table 7 shows TS-2 wherein all pine areas are included regardless of age and then all pine areas including only those areas greater than 4 years old. Once this is done, close correspondence for the whole test site is achieved.

Table 7 - Landsat Classified Data by all Pine Cover Type and by Pine Cover Type Greater than Four Years Old - Winter 1976

Cover Type	All Pine Percent	All Pine Diff.	Pine 4 Yrs. Only Percent	Pine 4 Yrs. Only Diff.
Pine	52.6 (73.9)	-21.3	52.6	+1.8
Other	47.4 (26.1)	+21.3	47.4 (49.2)	-1.8

2. Within individual units variations ranged more than in the total and for various reasons. In addition to the young regeneration situation, there is a major problem of over and under estimating based upon seasonal variation. This usually involved mixed stands only. Winter data tends to overestimate pine. The reason is in mixed pine-hardwood areas, the deciduous hardwoods are masked in the winter (leaf-off) by the residual pine, which in terms of density of crown, can be substantial. Conversely, in the spring and early summer during the hardwood flush of new bright green vegetation, these species totally dominate the area blocking out or overpowering the pine spectral signature. Two examples are shown below illustrating these points (figures in parentheses represents St. Regis' inventory).

a. Unit 268 - TS-1 Winter and Spring Data

Cover Type	Winter (Percent of Total Area)	Spring (Percent of Total Area)
Pine	52.4 (46.1)	43.7 (46.1,

Note in (a) the reversal between winter and spring classifications results. This phenomemon is not unique and illustrates the overstatement of pine in the winter and hardwoods in the spring.

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b. Unit 338 - TS-2 Winter Data Only

Cover Type	Pine Class	Pine + Pine Hardwood
	Percent of Total Area	
Pine	69.8 (42.9)*	69.8 (67.3)

*Pine less than 4 years old not included.

In case (b), a large pine-hardwood classed OA had 75% of the volume in pine. This criteria alone qualified the area for a pure pine classification. In the view of those making the field decision at the time, it was really more of a pine-hardwood situation; hence the designation. The scanner picked it up as pure pine. Redesignating and adding this OA to the area of pine cover, brings close correspondence to the classified Landsat data.

Along with those pine areas less than four years old, it can be safely said that lightly stocked stands of any species mix (less than 5 cords per acre) are totally unpredictable. Generally this unpredictability becomes a matter of classification confusion, which in itself is information, and suggests such areas can be isolated from others as a separate stratum. The ability to stratify even broadly within a given species group, implies a generalized quantitative capability in the data beyond that of mere cover type mapping.

While the technological results of satellite image processing went beyond the initial hope of the project and fully satisfied objectives one and two, certain caveats should be heeded when contemplating the use of these data in an operational information system. For example, Landsat data and image processing do not represent a panacea. For some uses, Landsat performs well, for others, not well at all. It has been our experience to note Landsat data provides the greatest benefit to those users who know essentially nothing about their resource, or conversely to those who know a great deal, as does St. Regis. For specific data with regards to individual tree parameters or other high resolution needs, Landsat 1, 2 and 3 can be ruled out for the most part. Thus, Landsat data does not represent a replacement for traditional sources such as photographs and ground sampling, but rather an augmentation leading to a less time consuming, more efficient data gathering methodology.

The picture rapidly changes if Landsat data can be supported in some fashion. The registration of imaged data to a geographically referenced data base with associated attributes is one such augmentation. Such a data base was, in part, in place in Southern Timberlands. The computer based tabular inventory has been described. The only function left now in non-digital form, the mapping, was to become the geographic referencing base for the entire system.

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3.22 Interactive Mapping System

In the context of FRIS, interactive mapping implies a computer based graphics system tailor made for land use applications, allowing the user direct communication with the system as maps are created, edited or changed.

A major key in the St. Regis implementation of FRIS, is the ability to relate image processing results to the other data input into the information system. The system must merge inventory and other alphanumeric data with the digitally processed image. Both these data functions must be then registered to a common geographic location. If it is to be a map, and that is generally the case, then map rectification to ground locations becomes absolutely critical if one is to avoid the subtle if disastrous pitfalls of accumulated errors. It is re-emphasized that the mapping function, once considered ancillary, becomes the very centerpiece of the entire system; the reference base to which all other data are registered. To establish this base, line maps must be electronically digitized to form an independent file of data that can be overlayed on the classified image data set. Conversely, the imaged data set must be such that it too can be overlayed onto the map base. The problem rests in the fact that both these spatially oriented data functions reside in totally different formats as described below.

3.221 Data Forms

Although the image, map and tabular data bases are in digital form, the spatial formats of map and image differ, and each is different than the tabular alphanumeric data of the field inventory. The spatial formats involved are illustrated in a simple way in Figure 12.

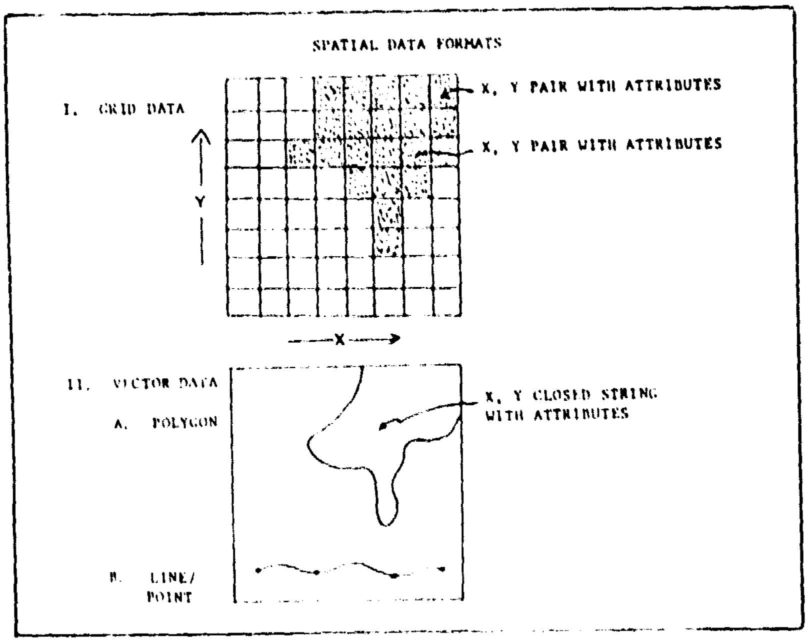

Figure 12 - Spatial Data Formats Depicting Gridded, Vector, Line and Point Data

Grid Data: Typical of digital imagery, grid formatted data are also referred to as raster data. A gridded data set is generated line by line, with each line being composed of individual picture elements or pixels representing the minimum resolving limits of the system. In Landsat 3 imagery, for example, each pixel represents some .3 ha (.8 ac). A raster or gridded scene can be considered as a matrix of lines and columns of pixels. Each pixel has a unique data value (attribute) and an addressable location relative to the scene in terms of an x, y intersection. Gridded Landsat imagery that has been classified represents, singly or in combination, polygons with attached attributes (each cell with its unique classified value).

Vector Data: Typical of drafted line maps, vector data represents lines in digital form. Multiple line entities aggregated into closed complex shapes are called polygons and as such are treated as single entities. Most map features are in the form of polygons, while several features might be depicted as single lines or points such as power lines and section corners. When line maps are converted to digital form, they are done so within a file of data with x, y coordinate control. From any reference point in the file, all represented lines, complexed into polygons or not, have a measured direction and magnitude in terms of x and y; thus, the term vector is appropriate.

Line/Point Data: Line/point data are a third data form typical in a graphics data file. These data refer to a single line or a point as against a closed figure or polygon. Line data would include such things as center lines of roads, railroad, powerlines; etc. Point data might include property corners, research plots and other monuments of cartographic interest that occupy just a point on the ground.

3.222 Maps: Data Entry, Storage Construction

Digital map data entry is typically done from a data input station similar to that illustrated in Figure 13. In this illustration, a digitizing table and supporting T.V. monitors represent the core of the station. The table itself is a fine wire mesh (grid). While the resolution can vary, 003 cm (.001 in.) is not uncommon. Unlike gridded data, cell content is meaningless here. The grid represents a locational function only with each network intersection having a unique x, y address.

Included with the digitizing table is a cursor with crosshair. The grid intersection closest to this crosshair is energized when the cursor is activated. In this way, line ends are recorded and stored. In a situation where a map is tied down to the table as shown in Figure 13, the corner coordinates are located by the cursor and the values keyed into the system with a data entry alphanumeric keyboard. The coordinates establish the domain of the file (map) and the spatial integrity of all the interior cartographic entities. In digitizing, data points are recorded each time a line direction changes. Since only the line ends are digitized there are no curved lines at all, by definition. The sharper the change in direction or curve, the more data points (short line segments) are required to define the geometry. Figure 14 illustrates how a map is digitized and the data stored.

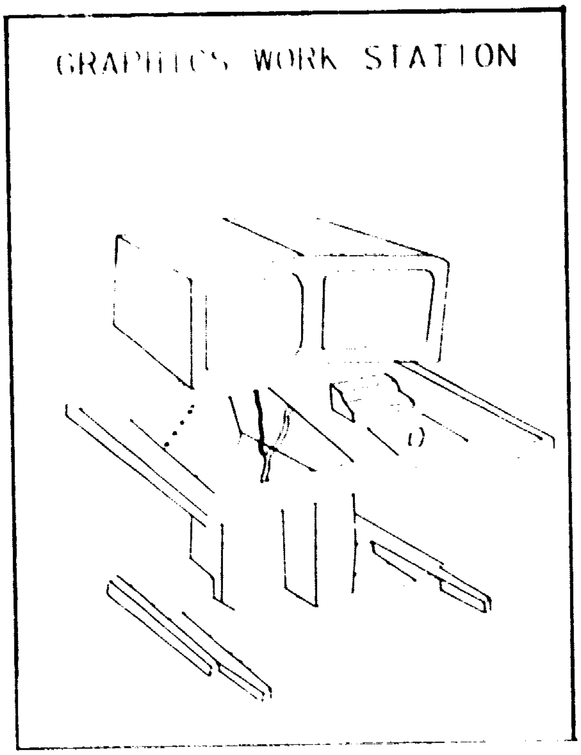

Figure 13 - Typical Graphics Data Entry Work Station

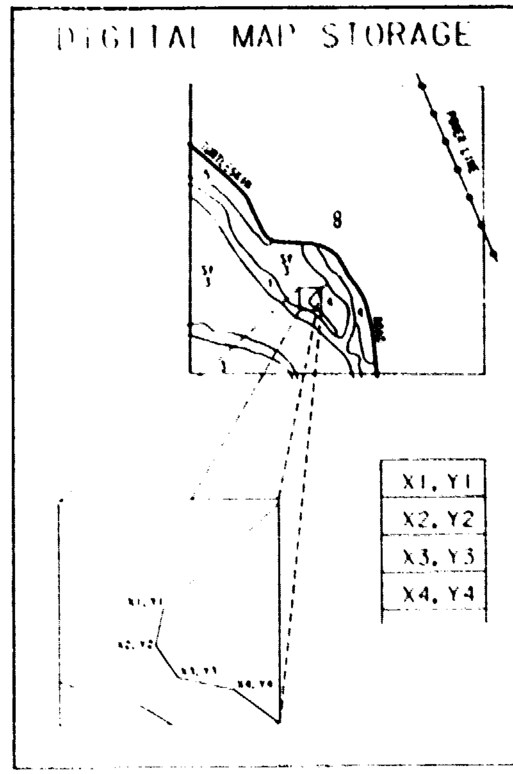

Figure 14 - The Mechanics of Digital Map Storager

Once digitized, the map resides in the computer in arrays as x, y values. From these data, maps can be drawn on a plotter and the work of a draftsman has been electronically duplicated, with one major improvement: a layered data file. Such a file is created level by level with each layer consisting of only those features normally considered together. All layers of information are registered one to the other and can be accessed singly, in any combination, or all together. Typical layers might include: geographic subdivisions; roads, railroads and other cultural features; property boundaries; cover type and topography. Figure 15 is an example of this layered data base concept.

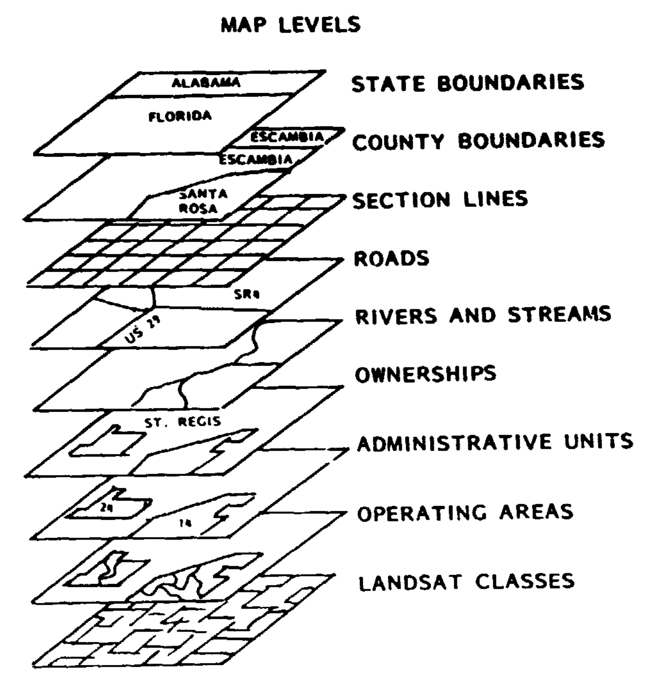

Figure 15 - The Concept of a Layered Data Base

3.223 Analysis

In the world of computer aided mapping techniques, more generally classed as geographical information systems (GIS), there are vocal proponents of both the gridded data base approach, typified by the early Harvard Grid system and elaborated on generously since, and the vector/polygon approach fostered by many "turn key" vendors as an outgrowth of computer aided design (CAD) technology. Although over-simplified, the crux of the difference centered around the ease of computer analysis and data manipulation with gridded data; albeit a horrendous data storage problem. Vector data, on the other hand, were most adaptable for mass storage, but created difficulties in access for manipulation or analysis. With the rapid growth of computer related technology, these problems may no longer be limiting. However, the requirements of FRIS dictated a preference to maintain the integrity of each data base in its own form; for example, maps still had to look like maps for credibility and user acceptance.

Polygon processing offered a very powerful addition to a vector data base and should be exploited if possible. The Boolean operators of intersection, union and complimentary functions are illustrated in Figure 16. It should be noted that filtering is a special case of intersection. This process becomes intriguing when considering multiple layered data and the capabilities afforded by computer aided analysis. The mapping function now has a dimension never visualized even a few years ago.

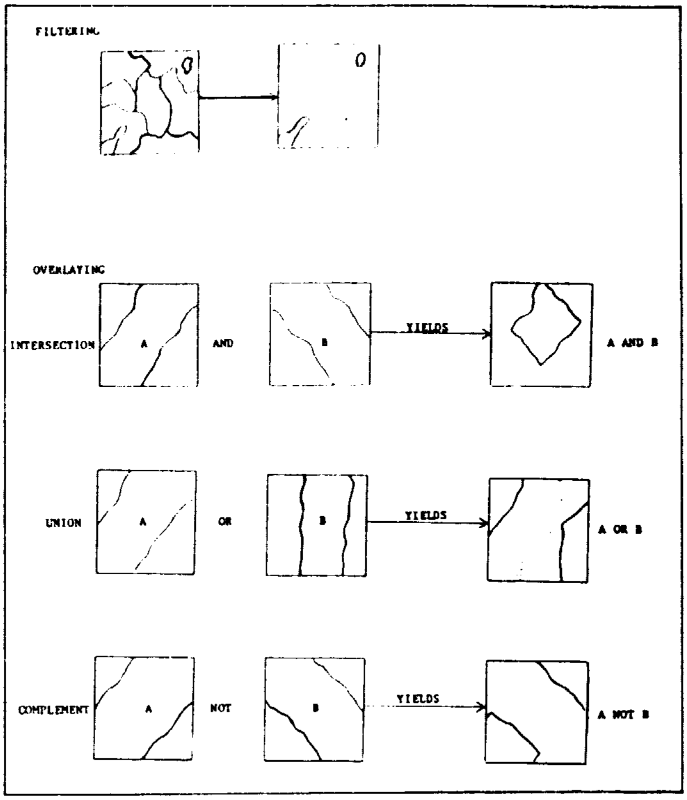

Figure 16 - Polygon Processing Methods for Graphics Analysis

Such a capability does not come free. The decision to proceed to operational status represents the single-most ambitious resource commitment of the project's implementation. While previously a one-time effort, the digitizing of 924.3 thousand ha (2.3 million ac) of St. Regis lands within the Southern Timberlands Division represents a highly labor intensive undertaking of major proportions. While clearly mundane, this task is in no way trivial, and must be executed with skill and at the precision level commensurate with the demands on the system.

3.23 The Linkages

To be responsive to the FRIS needs, the three independent digital data bases of imagery, maps and attributes must be linked through transformation software. This linkage must allow for multiple data base access, merging and analysis, while maintaining independent integrity.

3.231 Attribute Linkage

Attribute linkage deals primarily with linking the inplace inventory and other alphanumeric data to the map such that cross access and referencing will be possible. Such an attribute management system (AMS), must operate

as a subsystem of FRIS. Of the two major data base management concepts, hierarchial and network, the hierarchial approach was seen as more appropriate for FRIS applications. The hierarchial concept is likened to a parent/child relationship where the major block or unit (parent) is related to all the subunits and branches thereof (children) through a single path. This fits in with the St. Regis Southern Timberlands hierarchy; Figure 17A. Linkage to the files of the geographic management system (GMS) is through the smallest unit desired in the analysis or report. Access is then available from that level upwards to higher levels, all the way to the parent if desired. Each region within Southern Timberlands forms its own data hierarchy. The information can then be pooled with other regions for divisional reporting as required. Figure 17B illustrates the relationship (linkage) of a divisional AMS file and the individual regional or subregional GMS files.

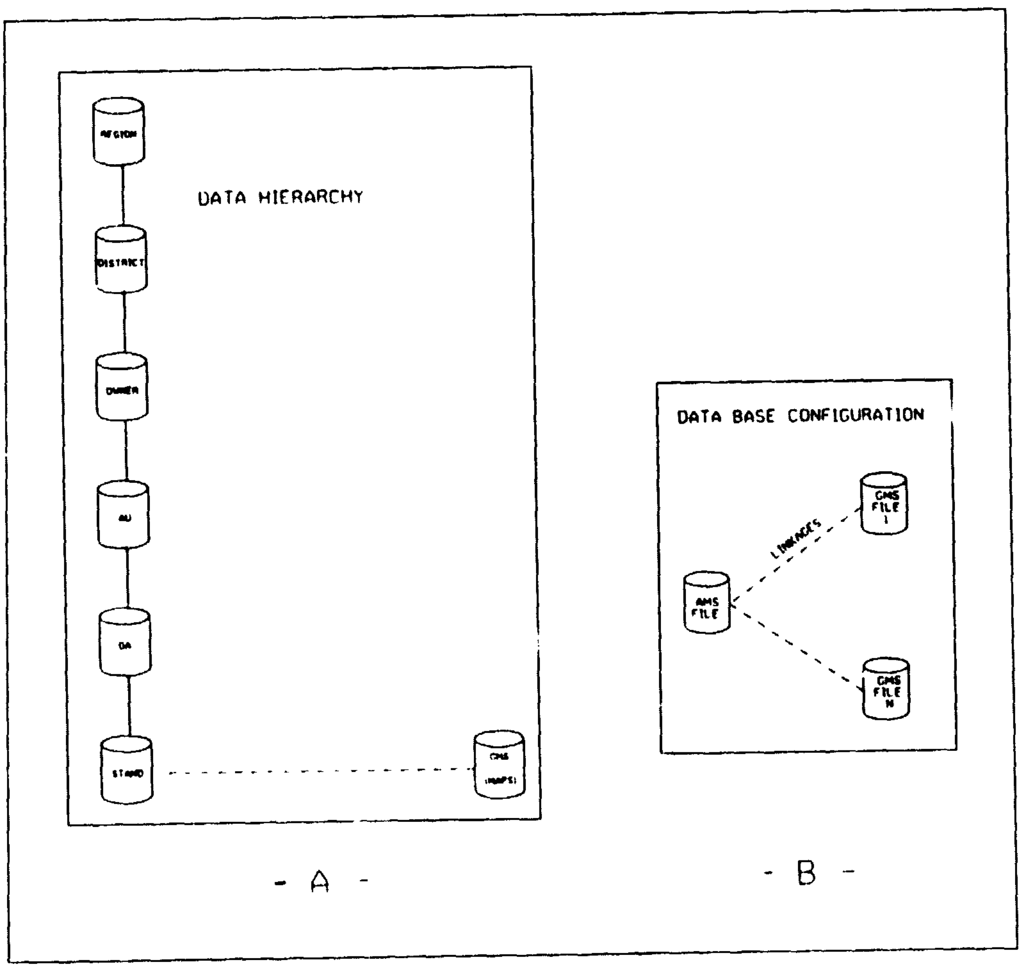

Figure 17 - Attribute and Geographic Management Systems; Hierarchy and Configuration.

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The linkage between the GMS and AMS is accomplished through identifiers. For example, a stand number with its Operating Area and Administrative Unit numbers is unique within a Region. Figure 17B illustrates the data base configuration.

The establishment of the linkage is not a trivial matter, and must be done interactively at a design station. Here attribute identifiers; i.e., AU, OA, and component stands are linked to the map elements. Through the GMS, map element commands are created and attribute commands attached. This process links the map elements to the stand identifiers; Figure 18. The stand linkage file is then merged with the entire attribute or stand file. The files are then batch loaded into the system and are correlated through a command processor which creates a linked attribute file. This file is then correlated with the newly created GMS file with linkage to the attribute file. The relink command definition is invoked if the file is changed in any way. Modification and relinking will be a part of the yearly updating task.

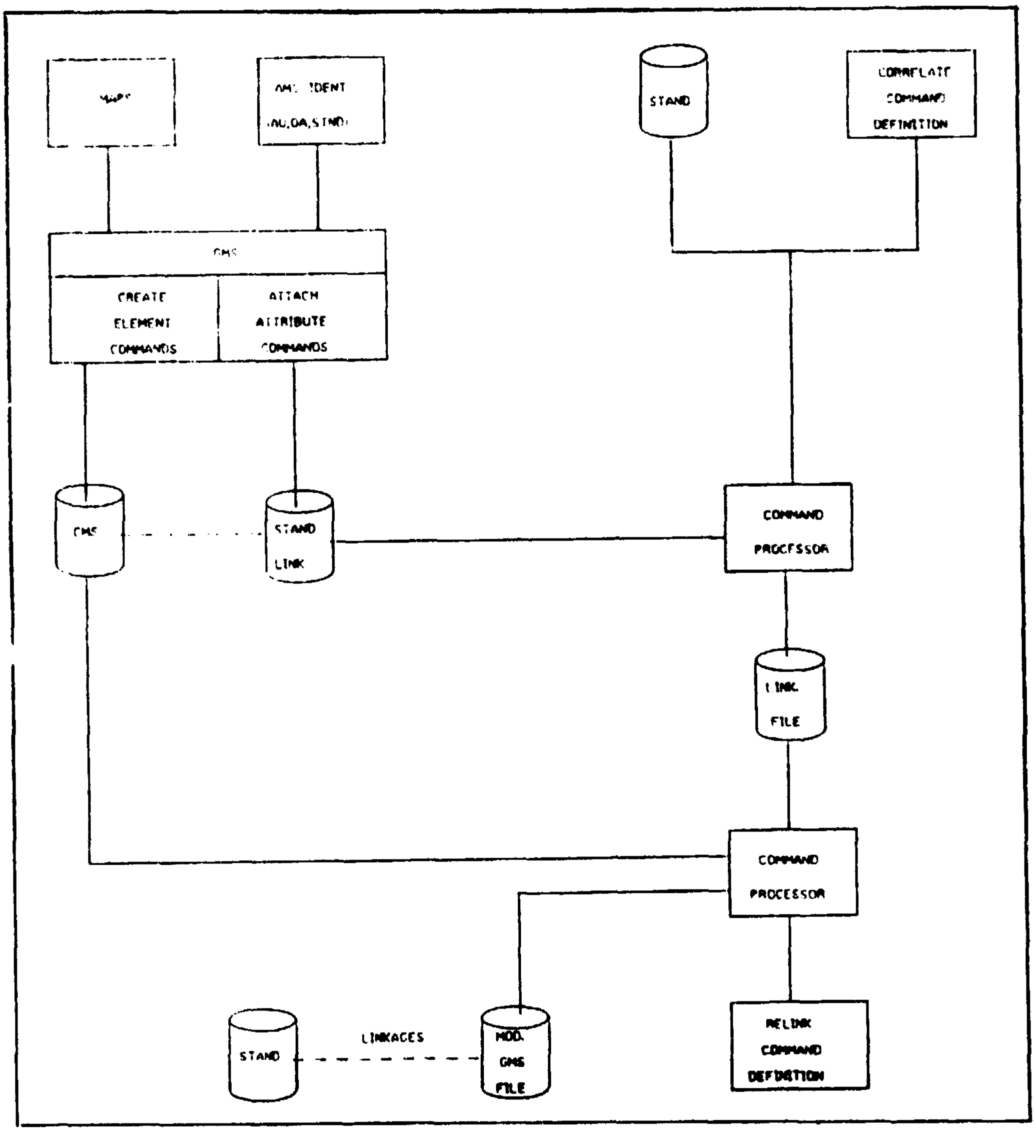


Figure 18 - The Loading and Linking of the AMS and GMS

At the time of this writing, there is no known procedure to automate the creation of element commands and the attaching of attribute commands establishing the basic linkage. Once done, however, it is merely a matter of relinking selected areas as needed during the updating cycle. The power of these linked data bases can hardly be overstressed. Tabular summaries based on geographic parameters or conversely maps generated reflecting spatial distribution of preselected attributes, will be possible with the whole set of Boolean operators of intersection, union, and complementary functions as described earlier. In addition, through operating area linkages, pertinent financial data can be accessed and long range planning models can then be run in a spatial environment. By seeing where operations will occur if the model is followed, the practicing forester can make an assessment as to the viability of his options from a purely practical standpoint. It should be re-emphasized that an attribute (inventory) and graphics capability, although not totally automated, were in place as an operational entity at the outset of the FRIS project. It should be further stressed that at least this level of information is required as a prerequisite before FRIS can be considered as a viable option; thus, with an AMS and GMS, FRIS can become a reality with or without imagery.

3.232 Image Linkage

The problem of image linkage is a special one and not one normally addressed by the typical graphics design community. Automated digital image processing represents another data source to FRIS, a dimension of capability never before possible, and data not available from any other source. Like attribute data, imagery is absolutely dependent on the graphic data base as a spatial referencing framework, rectifying the bounds of the imagery to known geographical locations. LARS had faced this problem and had a basic understanding of the graphics rectification problem; however, their need was to fulfill a research and teaching commitment, and the procedure was at best cumbersome and tedious to implement. In no way could it be considered operational without a great deal of work.

The gridded or raster format of Landsat digital imagery has utility from an analysis and data manipulation standpoint. This format will also be beneficial in integrating digital data from other sources. Because of this, the initial design of an image management subsystem (IMS) becomes extremely important. Vectored data as represented by the GMS has great utility also. Spatial integrity, precise boundary definition and user oriented output products all make this data base format essential in an operational FRIS.

Given the established linkage between the attribute and geographic data bases, similar linkages must be developed in an automated context between the imagery and geographic data bases. In addition, such attributes as might be assigned to the imagery features must be entered as part of the attribute file.

In assessing the problems associated with automatic registration of vectored map files with gridded image files, consider Figure 19. In this figure the overlay problem is illustrated with a decision rule described.

Here, a polygon (B) is overlayed on a grid (A). Only the whole cells within the polygon carry its attribute, 1. All other whole cells carry the external attribute 2 (C). The question is: how should the split cells be classified in terms of attributes, given only one value per cell?

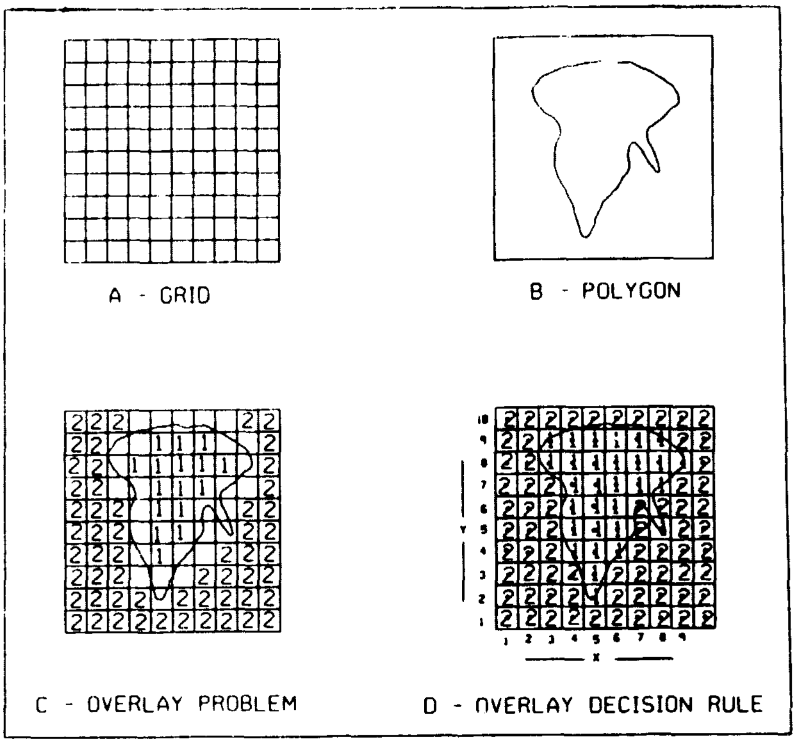
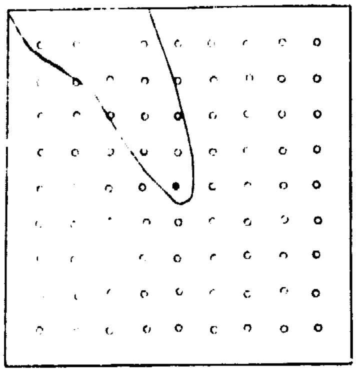


Figure 19 - Vector to Grid Overlay Decision Rule by Center Dot

In this illustration, a center dot decision rule shows one technique. Simply put, the cell carries the attribute in which the dot falls (D). This rule is rather coarse, and in some cases could be misleading, especially in data sets with intricate boundary definitions. For example, in cell X8, Y5 in Figure 19D, a narrow point of the polygon just catches the center dot, and yet most of the cell's content falls on the other side of the boundary. If this sort of inaccuracy is going to present a real problem other than just an occasional boundary "glitch", then another decision rule would be appropriate. Such a rule could be one of predominant points; that is, instead of just one center point - fill the cell with a multitude of points as in the following illustration. In this example, the majority rules decision logic would clearly put this cell into category 2.



Predominant Points Decision Rule; Cell X8, Y5

Another and more simplistic decision rule is especially suited for roads and boundary lines, such as property. In this case, the decision is one of yes (1) or no (0) based upon the absence or presence of an element within the confines of the cell. Figure 20A represents a simple map with boundaries and a road overlayed onto a grid. Any cell through which a line (boundary or road) passes is given an attribute of 1. All free cells, the attribute of 0. The result is shown in Figure 20B.

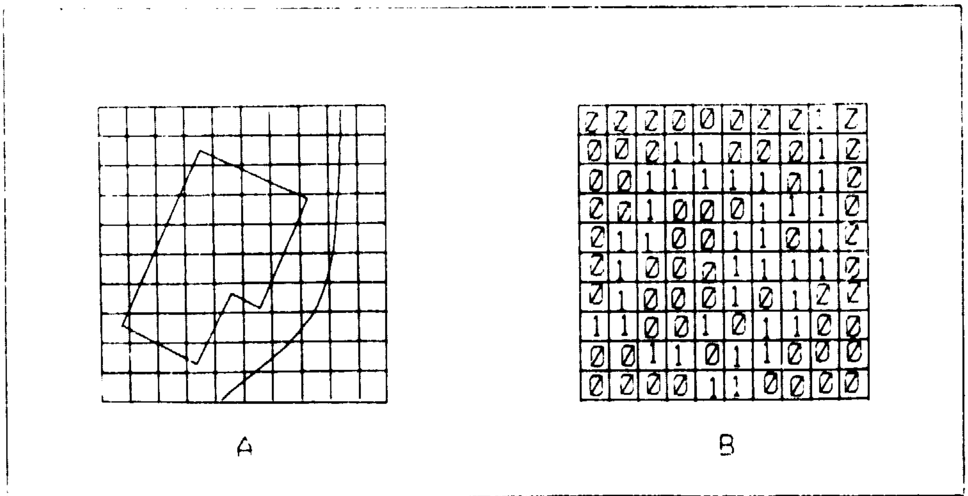


Figure 20 - Absence/Presence Decision Rule

Figure 21, A-F summarizes the polygon to grid conversion (A-C) and the converse grid to polygon conversion (D-F). Using the center dot decision rule for simplicity, the map with its attributes (stand number) is overlayed and registered to a gridded data set (Landsat). Based upon the center point, the gridded data set is coded with the appropriate attribute, (1-4). It is in this form that Landsat classification analysis will take place, with locational and descriptive help being provided by the existing maps. It is absolutely essential that good registration is accomplished between the map and Landsat data. Once the analysis is done, the gridded data can be transformed back into polygon form. Although there is a blocky or stairstep look to the results, the original polygons are clearly represented. The resulting polygons are created by generating boundaries on the gridded data set everytime the data values

change. As the polygons are formed, they are in the GMS format and are already complexed into closed polygons. The classification results establishing attributes for the features in polygon form, are also carried over into the AMS data file, with the linkages to the GMS file already established. Through the AMS linkage, the IMS and AMS are linked through commonality with the GMS.

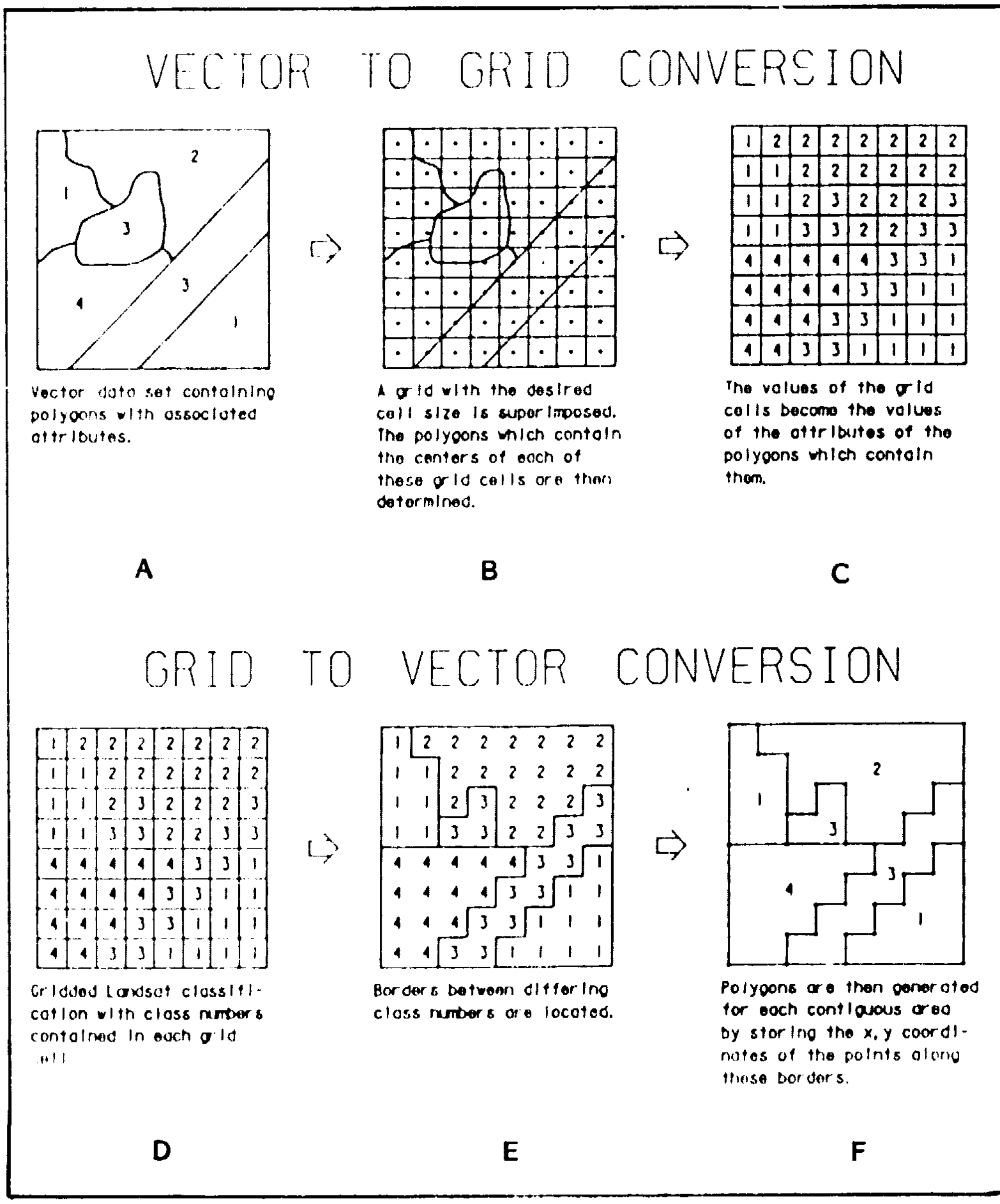


Figure 21 Summary of the Vector to Grid -Grid to Vector Transformation Philosophy

3.233 Change Detection

With the demonstration of image processing and graphic capabilities, the establishment of the linkages between them, and the attribute file, most of the project's objectives had either been met or addressed. Classification and manual overlay comparisons satisfied the land and timber stratification, and the Landsat to photo correlation objectives. Interactive graphics demonstrated not only an automated annotation capability, but opened up a whole new area of analysis possibilities never considered at the outset of the project. The ability to link the graphics data base with the imagery provided an automated registration and annotation of Landsat data for ease and accuracy of analysis, and the capability of displaying the results in map form familiar to the user. Linkage capability has provided the means by which to implement change detection procedures through numerical analysis, and has provided the vehicle by which the digital data base forms of imagery and graphics can be integrated into the ongoing forest information system. This will be discussed in more detail in the following section on Preliminary System Design.

One of the strong features of Landsat derived data is the availability of repeat coverage on a prescribed periodic basis. As a general rule, yearly anniversary data will suffice for the great bulk of applications to be performed on a routine basis. The matching or registration of these anniversary data sets, and comparing them automatically through numeric analysis provides the foundation for the change detection procedure. Briefly, it is a comparison of the data values of classified features from one date to another. If these values deviate beyond the threshold of what might be expected, it is recorded as change. Using the linkage capabilities previously described, the change analysis can be easily done in gridded format with appropriate boundaries overlayed from the GMS. Upon completion of the analysis, the results can be converted to vector format and change maps generated for distribution to those in need of the information. Figure 22 is an example of such a map generated during the project by Harvard University's Laboratory of Computer Graphics and Spatial Analysis. In this illustration, a simple cross hatching technique is used to highlight the areas of change. In this case an AU map was compared to Landsat data collected three years after the map was drafted. The major area identified as pine by the inventory and classed as hardwood/other in the Landsat data were young pine plantations less than 5 years old. The imagery was picking up the bare ground values and will continue to do so until crown closure has an impact on the reflective values. Where the inventory classes a cover as pine/hardwood and the imagery identifies it as other (pine), it was found these were those wet pond and bay areas that had a predominance of pine cover, and were collectively grouped into an operating area classed as pine/hardwood.

In every situation, the change was logical and explainable either in terms of actual change or in what might be called an over-generalization of the type map, where classes are defined below the imagery's spectral or spatial resolution. This was very encouraging and represented a key technological factor in reaching a go/no-go decision for Phase III.

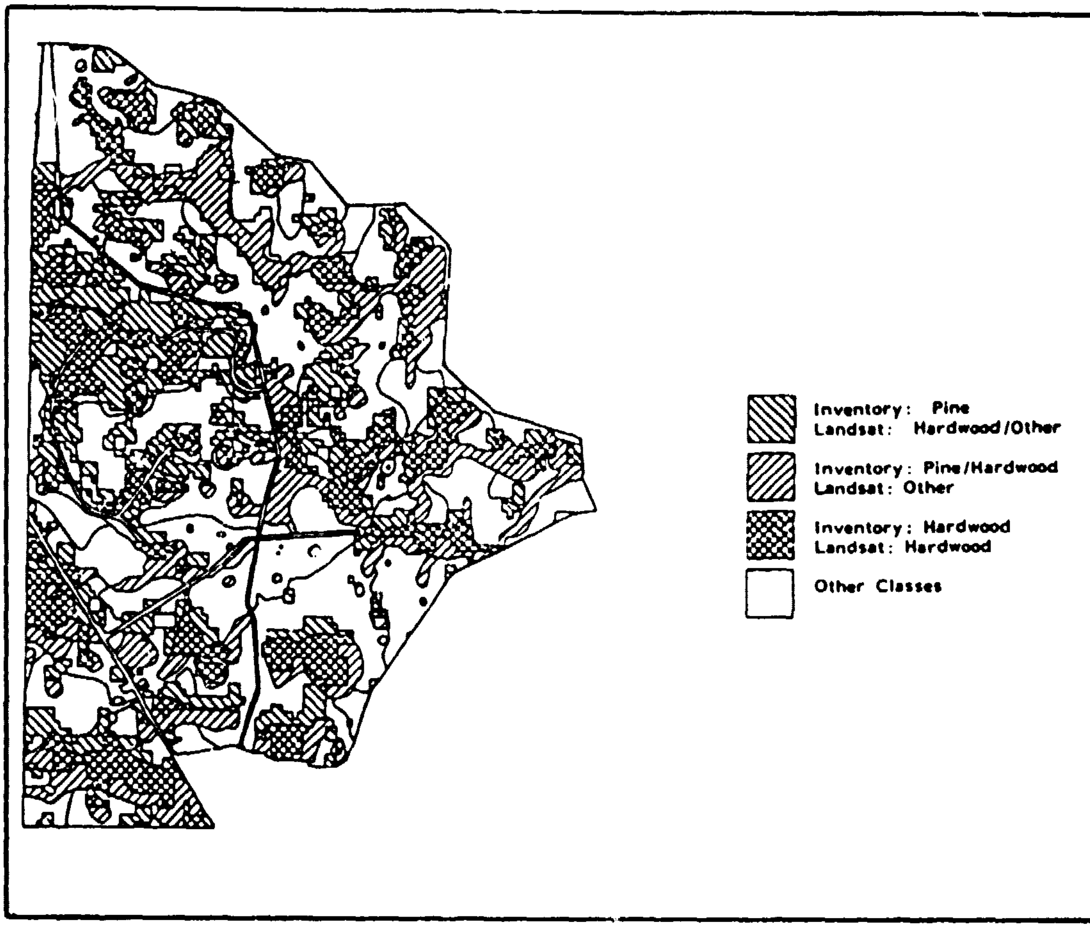


Figure 22 - Change Detection Through an Agreement Map

3.3 PRELIMINARY FRIS DESIGN

3.31 General Considerations

Preliminary FRIS design addresses directly objective 5 of the project plan, namely integration of the new technology with on-going forest information systems now in place. In designing a system, three major points must be kept in mind if it is to be successful. The system must be:

1. Easy to implement - For FRIS to be successful in a production environment it must be accessible to the non-technical user on a regular basis. The procedures should be easy to follow in "cook book" form, and the system must be directly accessible, with few if any intermediate steps.

2. Economically attractive - To replace an old system with a new one the new one must demonstrate not only the ability to do everything the old one did, but do it more efficiently, even if it costs no more. Implementation of new concepts must be worth the hassle of change In addition, any increase in cost must be matched by a parallel increase in benefits.

3. Credible to management - Confidence in a new system can be measured by its use. Many "good" ideas end up as academic "white elephants" either because they are difficult or troublesome to implement, or when they are implemented they don't have the support of the user (management). Some of the factors that will help in securing the support or confidence of the user include:

   - User participation - the user must be involved in the system right from the beginning, not as a spectator, but as a participant. Only during the problem definition stage and through actual hands-on experience will he become aware of the capabilities and the limitations of the system. The technology must be transferred with the system.

   - Assurance the system will perform as advertised - Not only does the technology measure up to expectations, but is the system reliable in performance, and is it providing the information needed and asked for?

   - Response time - Access and response of the system to the needs of the user is critical. Herein lies the need for an interactive link to the system.

Although the demonstration of the capabilities of the technology will go a long way toward instilling user confidence, the accessibility, and responsiveness of FRIS is the key, and it rests totally in the systems design. It should be stressed here that the system being contemplated is an information system. By itself it is nothing, and cannot add to earnings or profit per se. Only when put into the hands of astute managers can it contribute to the overall efficiency of operations and planning.

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3.32 Proposed FRIS design

The components of FRIS as proposed are illustrated in Figure 23.

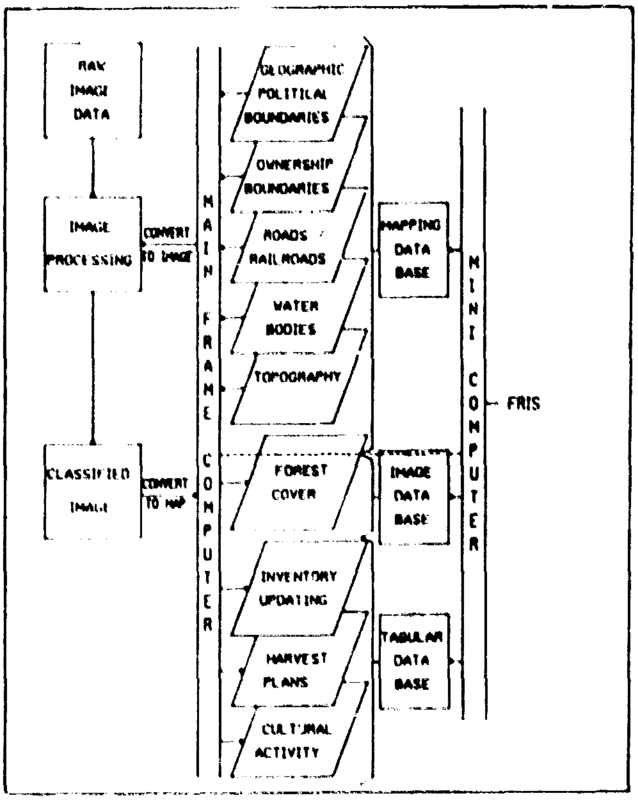

Figure 23 The FRIS Concept A Multi-function, Layered Information System

Here is depicted the three independent data bases, their interrelation ships, and structure. Each of the data functions (imagery, mapping and attribute) stand alone, but are related to each other through a common geo referencing base and are organized and managed by the FRIS data processing subsystem as registered layers of information. The data processing subsystem is based on a mini/host computer concept, wherein the mini computer satisfies the interactive requirements, while the host main frame satisfies the large batch processing requirement of the system.

3.321 FRIS Design Options

The cornerstone of the FRIS design is a Divisional FRIS Center (DFC) into which remote Regional FRIS Centers (RFC's) can have access. The RFC, while vital to the ultimate operationality of FRIS, is merely an extention of the DFC, and can be added as appropriate.

In considering the FRIS design configuration, two basic approaches were considered: (1) the development of an in house system integrating Landsat imagery and attribute data with a geographically referenced data

base, and (2) the purchase of an off-the-shelf package including hardware and/or software that would meet the FRIS requirements. Unless systems and applications programming expertise were available pertinent to image processing and computer mapping, a self developed system was not considered practical in terms of both time and cost of establishment. Since such talent was not available, and the prospect of gaining such was dim at best, this approach was abandoned as a viable FRIS option.

Of the off-the-shelf products meeting the FRIS requirements, two alternatives were available: a complete "turn-key system" packaged and ready to go, or a basic "bare-bones" system providing just the nucleus from which to expand.

The Turn-Key Alternative

In discussing this alternative, it must be pointed out that "turn-key" is used as a relative term only. It is probably safe to say that no system based upon computer technology can really be considered as turn-key in the context of a real estate transaction, if specific applications are involved. For the purposes of this report, turn-key refers to a system configuration that is publicly available, and meets the overall requirements of FRIS, such that the system can be installed and brought on line with little or no prestart-up activity. The vendor of such a system would be expected to provide the hardware and software, install both and be responsible for the maintenance of the entire system. In addition, adequate training and full documentation must be provided with the systems delivery. To have a system installed and maintained by a single vendor takes a big load off the user, and with a guaranteed system performance makes a most attractive alternative. Since many generalized applications routines are included in the software, immediate capability would be provided, given a compatible data base is available. Initial efforts could then be directed toward using the system to generate results instead of spending time on systems development.

While there were many systems to choose from, some based upon the gridded and some based on the vector philosophy, FRIS required a vectored concept, with two major prerequisities: a data base management system able to integrate attribute information with the graphics file, and vector to grid, grid to vector transformation capability. In addition, the vendor would have to demonstrate an immediate support capability for a remote regional graphics installation.

It was quickly determined that a turn-key system as described comes at a relatively high initial cost. In addition, the buyer is committed to the vendors choice of hardware, and does not have ready access to the source software provided for the system. Being a "plug-in" type system, the software is highly generalized to meet the needs of a wide range of users. The uniqueness in this type of system must be generated by the user through specific applications.

The Bare-Bones Alternative

In considering a basic "bare-bones" alternative for implementation, the scope of the FRIS configuration would have to be rescaled to include only a DFC, at least initially, with a minimum mini-computer facility. Operating FRIS in a basic centralized mode reduces sharply the computational requirements. With reduced time constraints on total divisional implementation, a bare-bones computer graphics software package could be implemented for FRIS. Such a package is ODYSSEY, developed by Harvard University's Laboratory for Computer Graphics and Spatial Analysis. Some analyses and output products from this software have already been demonstrated in this report (Change Detection). With such an option, the user would be responsible for the purchase, installation and maintenance of all the associated hardware and the compatibility of this hardware with existing facilities.

Although the basic alternative requires more time to implement fully and requires a higher in-house commitment to make operational, there are certain advantages to such a system that should not be ignored. Not the least of these advantages is the relatively low cost of installation. Once developed, the system using the basic software as a nucleus, would be essentially unique to the developing organization. This would include the desirable characteristic of being almost totally independent of vendors in terms of specific hardware constraints and proprietary software. With the proper level of manpower commitment for engineering and software development, a system better than the turn-key alternative could be developed over time. The emerging system would be totally customized and proprietary. The big question was; can the time and additional personnel be afforded?

The Phase II Demonstration Report provided to St. Regis management based its proposed system on the turn-key option. The reasoning was not only the time factor, but in the general aversion to "re-inventing the wheel." The preliminary design called for the installation, check-out and implementation of the DFC in 1980. As the system became operational, additional capabilities were planned for RFC's throughout the Division; Figure 24. It was contemplated that the RFC's would come on line as the cartographic data bases were established. The regional capabilities would put the system within reach of the user in an accessible and responsive way. It was not intended to provide the RFC with the level of analysis capability available at the DFC. The RFC would provide a review and edit function, with hard copy devices and only limited ability for analysis. Here updating and editing of inventory and maps could be done, classified imagery could be called up on demand, and output products generated as required. The proposed DFC configuration is illustrated in Figure 25, with a brief description of the hardware components. In addition to that illustrated, several alpha-numeric CRT terminals will be required for data input. Since the RFC's were not contemplated immediately, and in view of the rapid changes in technology that will effect the ultimate RFC design, no attempt was made at this time to configure these installations.

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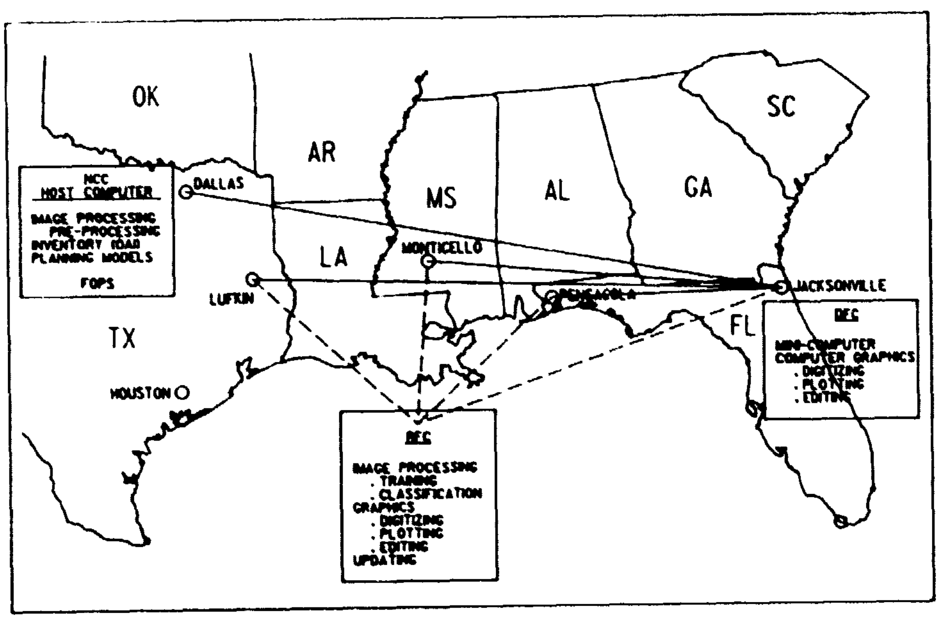
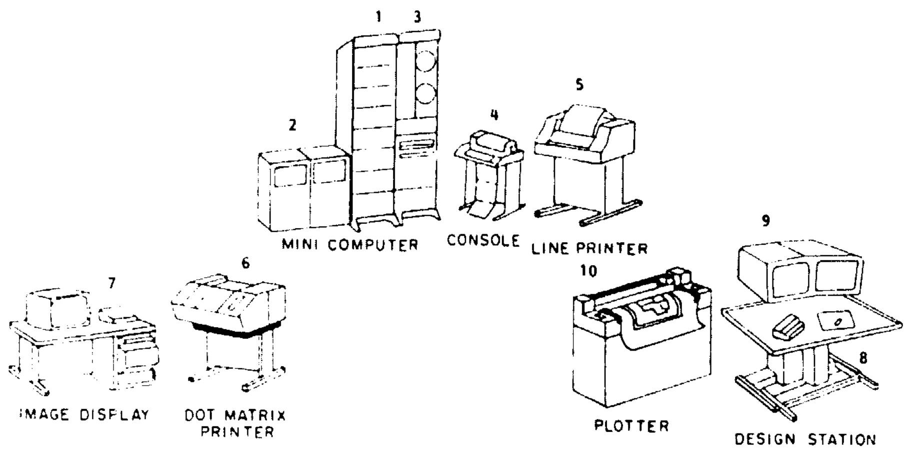


Figure 24 - FRIS as a Distributed Processing Facility



ITEM	FUNCTION
1. Central Processing Unit (CPU)	A mini-computer with 512-1024K bytes of memory.
2. Disk Units	Resource Information Block data base; work space.
3. Magnetic Tape Drive	Image processing data, library tapes, historical files, long term storage.
4. Console CRT/Printer	Data input/output (small scale), remote job entry (RJE), diagnostics.
5. Line Printer	Tabular output products; image data output for training and classification.
6. Dot Matrix Printer	Image gray scale for location; registration and classification results.
7. Image Display CRT	Registration of Landsat to known coordinates. Training for classification. Edit of classified results in an interactive mode.
8. Digitizing Table (40 x 40)	Large map digitizing capability needed to establish the data base.
9. Graphics CRT	Editing, preview and change in real time.
10. Drum Plotter (36" multi-pen four color)	Basic graphic output on large format (4" - 1 mile, etc.) and composites.

Figure 25 - Divisional FRIS Center - Hardware Components and Functions

3.33 The St. Regis Commitment

In committing to the FRIS concept, needs in three areas must be addressed before the concept can become a reality: personnel, equipment and shelter.

3.331 Personnel

If FRIS is to be successfully implemented in an operational environment, it is essential that it be properly staffed, not only to install it, but to provide the basis for growth. The major areas of expertise required include; cartographics, inventory and sample design, remote

sensing and image processing and computer engineering and data processing. While these personnel specialties were required if FRIS were to be successful, they had to be provided within the current framework of available positions (but not necessarily individuals). The establishment of new positions was not an implementation option.

- Cartographics: Basic cartographic experience has long been a strong St. Regis capability. Establishing control and drafting maps has been an on-going activity paralleling that of inventory. The notion of computer based mapping is still predicated on time honored principles of cartographics, but it is largely automated and requires a new perspective on the whole discipline. Retraining existing personnel is of course desirable, but attitudes must be matched to the task at hand. This means first and foremost a willingness and desire to retrain. Once identified, the individuals would likely have to be reassigned to FRIS which might mean a physical move. This would have to be a joint commitment of both the person and Southern Timberlands.

- Inventory and Sample Design: Like cartography, in-house capability was available. The need was in the area of conceptual sample design, and how FRIS could be brought to bear in providing the basis for more efficient sample design and inventory data gathering procedures.

- Remote Sensing and Image Processing: Here there was no resident expertise. The area of remote sensing and image processing was one that was reasonably new, at least in an operational application. Since the basic premise of no additional positions had to be adhered to, vacant positions had to be found to provide entry for the skilled personnel needed.

- Computer Engineering and Data Processing: Here another highly skilled position was needed. The idea of a mini computer was a new one to Southern Timberlands, and the idea of a computer installation with different equipment than the traditional St. Regis facility was new to St. Regis. Contrary to most vendors claims, a turn-key interactive graphics system just does not materialize and run itself. It needs a lot of help. In addition, as suggested earlier, the need for specific applications will require software modifications almost immediately. To meet these new requirements, strong software support will be needed.

3.332 Equipment

The basic equipment requirement has already been outlined in the section on the FRIS design options. Although the RFC's could be deferred until a later date, the DFC was central to the whole concept. It is important that the data acquisition, analysis and results be done and provided in a timely manner and that the data base be responsive to query and change. Deletions and short cuts in the basic hardware/software configurations would frustrate the implementation effort to the point of being counter-productive. Without this commitment, the success of the entire system would have been extremely compromised, and put into jeopardy.

3.333 Housing Facilities

Providing the room to establish FRIS and to provide for its growth was essential. The facilities available at the Southern Timberlands headquarters were totally inadequate to support such a system. Some space had to be provided with the environmental control necessary to house the array of equipment needed for FRIS. The facility must be adequate enough also to provide the room necessary for work space and archival storage.

3.34 Major Benefits Summary

Through FRIS, it is anticipated that significant improvements will be possible in the current forest inventory and manual mapping system. Also, several new applications will result relating to new acquisitions and outside wood availability/accessibility information.

Forest Inventory: The in-place forest inventory (OAI) and updating the data base as used by operations for management and planning purposes, will unlikely be altered in any material way by FRIS; however, the means by which the data base is derived and maintained will be significantly improved by (1) stratification of land and timber types providing a level of prior knowledge for many applications, (2) detection of changes in the forest on an annual or other desirable periodic basis, (3) improved sample design afforded by a prestratification capability, and (4) timeliness of the results.

Mapping: The in-place inventory has been supported by a non-automatic, non-responsive and labor intensive mapping capability. Because of the physical effort and time required, maps are typically drafted at the time of inventory, and with few exceptions, not updated between the inventory cycles. Because of a dynamic forest environment, the maps are obsolete soon after the inventory.

To be effective, a forest mapping system must provide more than a mere road map function. It must fairly represent the spatial distribution and associated areas of the forest cover at any point in time, and must be responsive to the user's needs as required for time and site specific applications. FRIS provides the potential to establish a complete and automated forest mapping system, including:

- A permanent digital map base

- An annual map edit and updating capability

- A variable map format and scale options.

New Applications: As important as it was to improve the efficiency of the current forest inventory and mapping system, it should be emphasized that at best this was an incomplete system. It either did not or inadequately addressed three other major areas of information needs within the Division: (1) land acquisitions - first look, (2) outside wood supply - availability

and accessibility and (3) information resource management - accessibility, responsiveness and retrievability. Almost as a bi-product, FRIS will provide a level of capability in these areas where none now exists.

Land acquisitions, first look: Each Landsat scene represents some 3.4 million hectares (8.5 million acres). In acquiring data for owned and controlled lands, coverage for a high percentage of potential land acquisitions will also be included. Through image processing and a basic automated mapping capability, FRIS will provide a quick first look at a prospective ownership as to cover types and density levels.

Outside wood supply and availability: Since outside wood comprises two-thirds of the Southern Timberlands raw material source, varied information on outside wood availability and accessibility and trends in land use and timber supplies is of critical importance. FRIS, with Landsat data as a backdrop, and with its map base reflecting counties, topographies and major land ownerships, will provide the area of current cover types and density levels, pinpointing concentrations of timber supplies. Wood buying efforts can be concentrated in those areas where availability would assure the greatest success, and where the growth seems to exceed the drain. With anniversary coverage and using change detection techniques, timber production and cutting trends can be analyzed and used advantageously in operations planning and monitoring situations. Region-wide trends and demographics can be achieved over time, which will highlight areas of growth potential.

Information resource management: Although data and information have been routinely provided to the user community, it has generally been done with a minimal amount of data management and with a format and periodicity predetermined by the provider. Deviations from the prescribed fare, in terms of both content and timing, were made only with great difficulty. FRIS represents not only a forest resource information capability, but for the first time provides the means by which information itself can be trated as a resource; an information resource management system.

Making such an information system available to the manager through the ultimate installation of the RFC's will allow him access and interrogation capabilities on demand, and will provide abilities for quick response to a variety of questions and issues. These could range from compliance in governmental regulatory demands, to assisting in the day-to-day decision making process. More importantly, with the total FRIS informadon base available and accessible, alternate strategies might be offered as options or even input to the regulatory process. This same capability will assist greatly in developing long-range plans and monitoring their execution. A generalized scenario of how FRIS might operate on an annual basis, from image processing of new data into updating and on into the planning and wood supply applications is illustrated and described in Appendix C.

3.4 ECONOMIC EVALUATION

At the beginning of the FRIS project, the economic evaluation criteria were identified and provision made to accumulate anticipated implementation and operating costs of the proposed system. Task Forces were formed to review interactive computer systems in terms of hardware and software,

and they were charged to recommend a system best meeting the FRIS requirements.

Time studies were taken in the field and office in an effort to determine in detail the factors involved and the performance of the inventory and mapping function at that point in time. Actual operating costs were related to performance, and unit costs were determined. By the end of the Phase II demonstration activities, the results of the various study panels were drawn together, reviewed and condensed to the basic conclusions considered most pertinent to an economic evaluation of FRIS. From this evaluation, a determination would be made at the project management level as to the feasibility of pursuing FRIS on to implementation, and to so recommend appropriate action to divisional management.

The impact of FRIS implementation would be in replacing the existing (but separate) forest inventory and mapping systems with an automated and integrated Forest Resource Information System. To the initial functions of inventory and mapping would be added a new data source; digital satellite imagery. Because of this approach, replacement economics must be considered by comparing the present and proposed systems. The system expansion associated with FRIS had to include the costs and benefits of using remotely sensed data, which was, after all the primary motivation for FRIS at the outset.

3.41 Statement of Economic Criteria and Assumptions

In a comparison of the costs of the present system with that of FRIS, both the 1978 actual cost and the 1979 operating budget were used. In areas of question, the most realistic or average costs were calculated. In some cases where annual costs fluctuate, as in aerial photography, a five year average was used. Production statistics (as area of inventory) were available from 1978 Activity Reports and from the 1977-78 time studies. The most meaningful year for comparison with the existing system will be 1984 when FRIS is fully implemented throughout the Division and its use is considered as routine. Evaluations were made, however, as a five year average for 1980-1984 so the progression toward implementation could be charted.

So that the potential for FRIS could be cast in the proper light, emphasis was placed on incremental (or out-of-pocket) costs, cost savings or cost avoidance. Expected benefits from the expanded information available from FRIS in general, and from satellite remote sensing in particular were extremely difficult to assess for two major reasons:

- Lack of experience data: As far as was known at the time, FRIS was the first real attempt to integrate Landsat data into an on-going information system, to say nothing of expanding on this technology into what has been described as a multilayered, fully integrated information system. Only the potential can be articulated. While there is always the chance this might be overstated, evidence to date suggests that an understatement was more likely.

- FRIS is only an information system and Landsat's multispectral scanner only a data collector. Benefits from the system will only accrue as the system is used and experience gained. It is difficult to assess at this point the impact on results of a "ho-hum" level of acceptance vs. an enthusiastic acceptance as a day-to-day working tool. How FRIS is accepted by the user is largely dependent on the system design and the effectiveness of the technology transfer activity. This is really the "bottom line" of the entire system, and has emerged as the greatest challenge to FRIS implementation.

The perceived benefits from FRIS as outlined in the results section of this report, come essentially free because of the integration with existing systems and efficiencies that will result.

3.42 Price Level Changes and Federal Taxes

No inflation adjustments were made in the projected costs or savings so that a better and less confusing comparison could be made with current systems costs in real terms. While it was expected that payrolls and materials would continue their upward spiral, it was also expected to be true for both systems. Contrary to most other costs, computer hardware seems to be falling rapidly. With so many unknowns, it was felt that a better assessment of the economics could be made if changing price levels were not included in the projections. The projections did not include Federal tax considerations. Depreciation, assuming a seven year life, was considered but this was actually a means to prorate the purchase cost of the hardware over its useful life.

3.43 Organizing and Staffing

In keeping with the preliminary system design recommendations, full staffing for FRIS was considered in the economic assessment. Figure 26

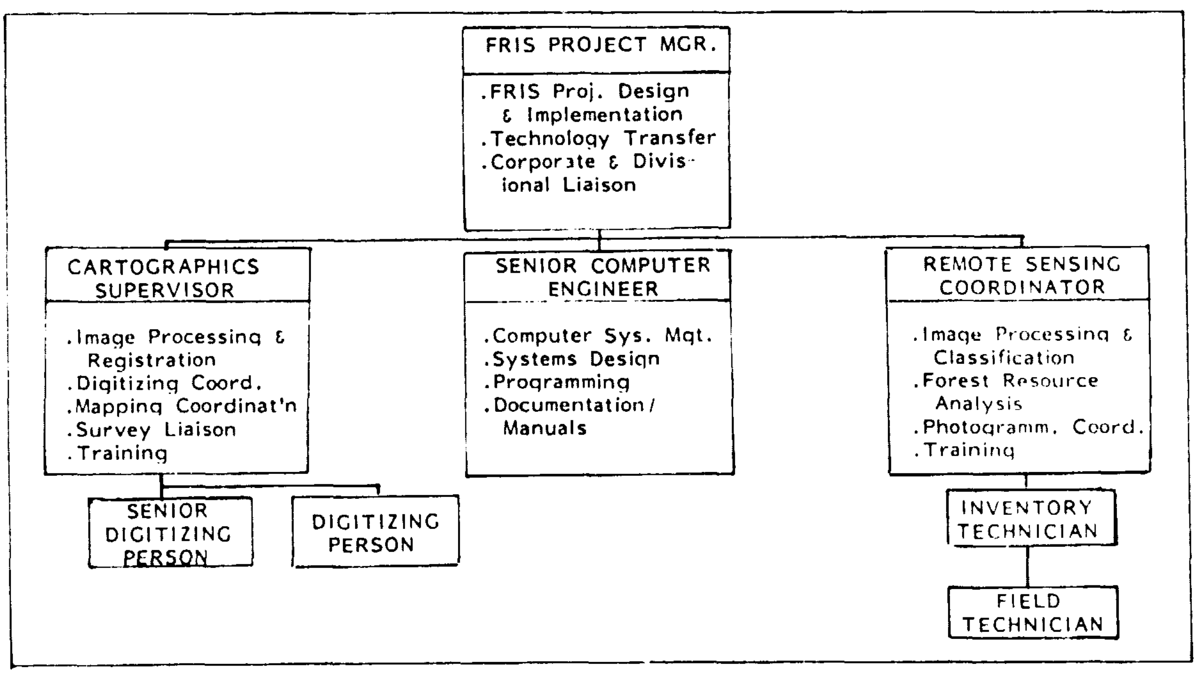


Figure 26 - FRIS Organization Chart (Proposed)

represents the proposed organizational chart for FRIS. While it is fully expected that some modifications will be made before implementation, it is felt that this fairly represents what is needed.

3.44 Cost Comparisons

In making the cost comparisons between what is being proposed and what now exists, only installation of the Divisional FRIS Center is included. Regional facilities will be justified unto themselves at the time of installation.

The largest single out-of-pocket cost of establishing the system is the high initial cost of the hardware and software for the system. Because of the estimated increased efficiencies of FRIS, it is expected that initial cost of the system will be retired in less than ten years. Over this period, the estimated annual cost of FRIS and related functions will be $1,054,600.

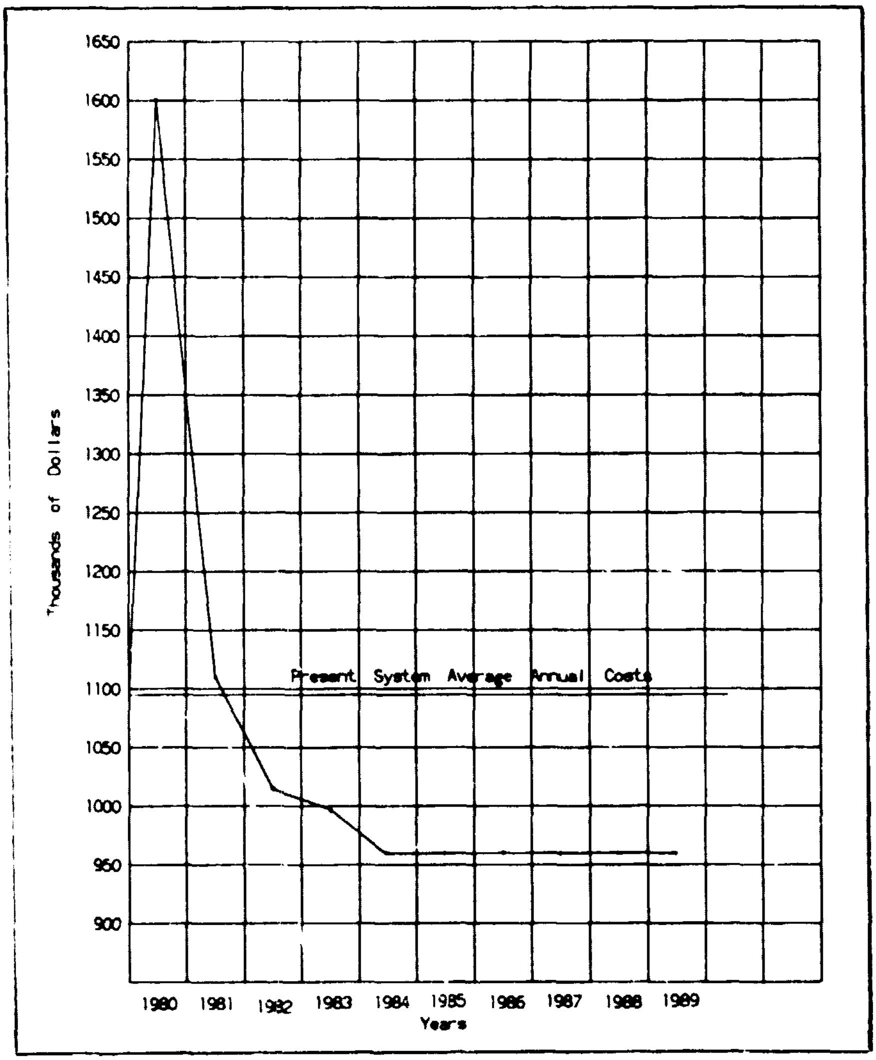


Figure 27 - FRIS Ten Year Cost Distribution

The cost projected for the current system over the same ten year period, given no changes, would average $1,091,000 per year. This amounted to approximately $1.13 per ha (.46 per acre) and $1.17 per ha (.47 per acre) for FRIS and the current system respectively. This amounted to a four percent difference between the two systems, or about $36,600 less for FRIS per year. The initial cost predicted for 1980 considering all the added equipment, personnel and facilities was expected to approach 1.6 million dollars, and then to drop rapidly leveling off near $960 thousand dollars by 1984. The ten year FRIS cost profile is shown in Figure 27. Costs of equipment and software wildly fluctuate, and almost on a daily basis. To give some relative idea of costs, however, Table 8 has been provided. This table is based on 1980 dollars, and is a fair representation of the cost of a vendor supplied turn-key system at the time.

Table 8 FRIS Hardware/Software Costs

Mini Computer System	$168,500
Interactive Graphics	
Input System (Digitizers, CRT's)	39,000
Plotter	23,000
Color Image Display Unit	73,500
Peripherals	15,500
TOTAL HARDWARE	$319,500
Shipping, Installation, etc.	27,500
TOTAL	$347,000
Software	
Computer Systems	8,500
Interactive Graphics	30,000
Data Base Management System	20,000
Other	32,000
TOTAL SOFTWARE	$ 90,500
TOTAL SYSTEM	$437,500

It is clear with only a four percent difference between the two systems, that the costs for operations were, for all practical purposes the same, but the allocation of the costs within the system were dramatically shifted; Table 9. In this table, the ten year cost comparisons of the two systems are shown by component. The greatest percentage change was in the increased costs for the computer and image processing systems; however, the greatest money change was in the area of inventory and mapping. In effect, labor was being

replaced by automation. If the decreased annual cost of $36,600 is realized, the initial hardware cost of $347,000 will actually be recovered in 9 years. Given this analysis, the additional benefits to be realized from the expanded FRIS, will be essentially free.

Table 9 - Cost of Present Inventory and Mapping Systems Compared with Proposed Total Forest Resource Information System 10 Years Assumed Life

FOREST INFORMATION SYSTEM	COMPUTER SYSTEM	IMAGE PROCESSING	FOREST INVENTORY	COMPUTER MAPPING	TOTAL COSTS
FRIS 10 Year Total	1,957,300	565,400	7,065,500	957,500	10,545,700
FRIS Annual Average	195,700	56,500	706,600	95,800	1,054,600
Present System Average Annual	129,000	-0-	795,000	167,000	1,091,000
Annual Change	66,600	56,500	(88,400)	(71,200)	(36,600)
%	+52%	+100%	-11%	-42%	-3%

4.0 PHASE III-IV SYSTEMS TRANSFER AND IMPLEMENTATION

4.1 PURPOSE

Phases Three and Four of the FRIS project were to be undertaken after the technical and economic feasibility of implementing FRIS as an operational system had been demonstrated, and a "go" decision made to transfer the system to St. Regis facilities. This decision was made at the divisional level, and Phase Three officially began on April 1, 1979.

In a modular project such as FRIS, no activity stands alone, but is interrelated with many other facets of the project. As such, much of Phase III activity really began during Phase II, and would run beyond and into Phase IV. To try and recognize the systems transfer and implementation phases as two distinct activities is almost impossible. Therefore, the two phases have been combined for the purposes of this report (7).

Designed to span 18 months, Phase III and IV activity was directed toward establishing a St. Regis in-house capability, within their complete control. To accomplish this, the following tasks had to be achieved:

1. Image processing systems transfer: LARSYS as documented along with several developmental and experimental processors had to be installed at the St. Regis National Computer Center (NCC) facility in Dallas, Texas. Personnel had to be recruited or reassigned and trained to run and operate the system.

2. FRIS design: Working from the preliminary FRIS design as proposed in the Phase II Executive Summary to St. Regis management, a viable FRIS configuration must be put together, including equipment and vendor selection, facilities and installation and organization and personnel selection.

3. FRIS implementation: Set up the major milestones and tasks to be performed to establish FRIS as an operational entity within the Southern Timberlands Division.

4.2 BASIC SYSTEMS TRANSFER

A major thrust of Phase III was to transfer the pertinent LARSYS software to St. Regis facilities and to generate additional software as needed. In addition, a core of competent analysts had to be established within St. Regis to implement the system once installed. The technical details of the transfer activities are well documented in the LARS Phase III Systems Transfer report to NASA: Mroczynski (4). This report will deal primarily with the St. Regis Phase III activity.

4.21 Software Transfer

Nineteen processors were transferred to the NCC in card image, 9 track computer compatible tapes. These processors represented some 42,000 lines of FORTRAN, 5,000 lines of Assembler and 1,500 lines of CMS (Conversational Monitoring System) EXEC language. The task facing St. Regis personnel was not that of volume, but that of converting from one IBM operating system and user philosophy to another, and to affect these additional changes meeting the basic NCC requirements in terms of format and security. Put simply, the overriding objective was to make the L/RSYS package operational within the St. Regis environment at minimum cost and disruption to the NCC. Figure 28 summarizes the conversion tasks undertaken at the NCC.

CONVERSION TASKS

LARS	ST. REGIS
IBM 3031	IBM 3033
VM/CMS	OS/MVS
Interactive	Batch
FORTRAN G	FORTRAN H
ASSEMBLY	FORTRAN H
Custom File Handling	Standard

Figure 28 - LARSYS Software Conversion Task - NCC

4.211 Systems Characteristics

LARSYS and the companion tape reformatting routines were written by the LARS staff over a period of years to run on a dedicated IBM machine under the CMS operating system. A satellite PDP 11/34, a mini computer by Digital Equipment Corporation (DEC), was used to allow users to communicate in real time with the operating programs. The system relied primarily on tape for sequential file processing. Tape handling and accounting were done by assembly language routines heavily dependent upon the operating systems construction. The LARS computer was almost entirely dedicated to this application.

While St. Regis also has an IBM machine, it is used primarily for commercial applications associated with the day-to-day conduct of business. The operating system is MVS and CICS is used for most real time applications. ROSCOE (a real time file editing package available from Applied Data Research) is also available in the St. Regis system. The system is strongly disk oriented, utilizing tape only occasionally. Because of the sensitivity of business applications within the corporate framework, assembly language routines which might touch the operating system were considered taboo and were not allowed.

4.212 Basic Changes

The following decisions were made governing the course and objectives of the conversion:

- Time accounting would be removed in favor of the normal in-house batch time accounting procedure.
- Tape handling routines would be rewritten in FORTRAN to do general file handling and to retain the necessary characteristics.
- The interaction of the PDP 11/34 would be removed as an unnecessary addition.
- ROSCOE would be used to initiate batch executions.
- The routine used to control the execution of the various LARSYS processors would be written in FORTRAN.
- LARSYS would be loaded as a complete system.
- System crash facilities which describe the error and return to the main memory, will be rewritten.

Additional changes, mostly minor, had to be made in both the tape reformatting routines and in LARSYS.

Tape Reformatting: The data as received from the EROS Data Center has a multiplicity of files on one or more tapes. This is generally incompatible with FORTRAN. A pre-processor was written in PL/1 to reformat the data into a single file.

Where linkage or entry points were required for program flow, but the routines were not, a dummy situation was set up to satisfy the program rather than rewriting them. In those cases where the statement was not needed at all, it was commented out. This procedure left the basic software in place, and conversion was accomplished through various bi-pass operations.

LARSYS: With regards to LARSYS, the same basic techniques were used to convert it. In this case, there were some assembly language routines that had to be rewritten. An important caveat must be recognized when attempting such large scale internal modifications to a software package such as LARSYS. Developed as a basic research and teaching tool, LARSYS had been generated over several years, and patched together to form the integrated package it represents today. Even though extremely well documented, there is the danger something will be missed, or restructured out of the original sequence. While this may allow execution, and may be even more efficient, in the event of an error, traceback routines can easily be reduced to chaos. Further, if not careful, RETURN statements can become hopelessly confused if not kept track of during modification.

Although desirable to eliminate all assembler language routines, at least from the NCC standpoint, attempts to replace byte manipulation software with FORTRAN compromised efficiency such that in running the

reformatting routines, a five fold increase in running time was experienced. Consequently, replacing assembly language in these specific applications was not considered feasible. As a result of this conversion an operational version of LARSYS emerged called LARSFRIS. The structure of this operational image processing package is illustrated in Figure 29.

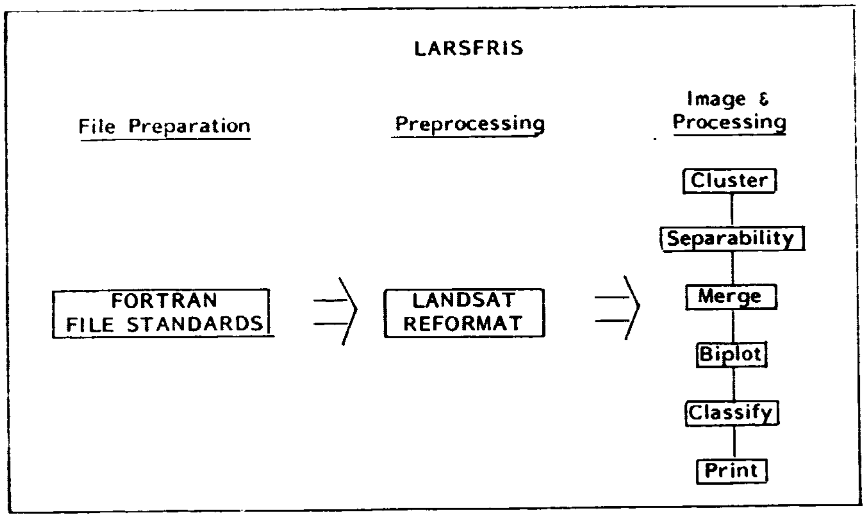


Figure 29 - LARSFRIS as a Modification of LARSYS

4.22 Training

The term "technology transfer" is unfortunately one of those phrases so overworked, it sometimes looses its meaning. For the purposes of this report, the phrase will be taken in a literal sense meaning to instill to the uninitiated an understanding and functions of new technological methodology, and how it applies to a specific use or application. In this sense, the term goes beyond a mere training interpretation, but does not incompass the broad range of meanings often used.

In image processing for FRIS, the hardware and software procurement and/or transfer was time consuming, but straightforward. In the area of analysis, the third part of pulling this technology together, image processing concepts were all but foreign to the average St. Regis employee and potential FRIS staff member.

4.221 The Transfer Link

In order to transfer image processing analysis capability to St. Regis, it was essential to provide the necessary documentation and equally important, a hands-on opportunity to work with the system and to fully appreciate the art of the discipline. During the course of Phase III, two such links were established with LARS: one to Jacksonville, Florida, and one to Dallas, Texas. These links served specific but different functions. The remote terminal to the NCC in Dallas from LARS saw limited service. Since LARSYS was so well documented, St. Regis personnel were able with very

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little difficulty, to install the system as delivered from the public domain.

The terminal to Jacksonville was designed for training and hands-on experience for potential St. Regis operators and analysts. The objective was to be able to invoke LARSYS processing and analysis from the DFC through LARS Purdue as it runs on their facility. Once the software was installed at the NCC facility, the same processors would be invoked from the DFC via the existing terminal already in place between Dallas and Jacksonville. This procedure would insure the installation was complete and providing the results as those achieved through the DFC and LARS. Any debugging or modification necessary could then be done through the existing terminals. The terminal configuration is illustrated in Figure 30.

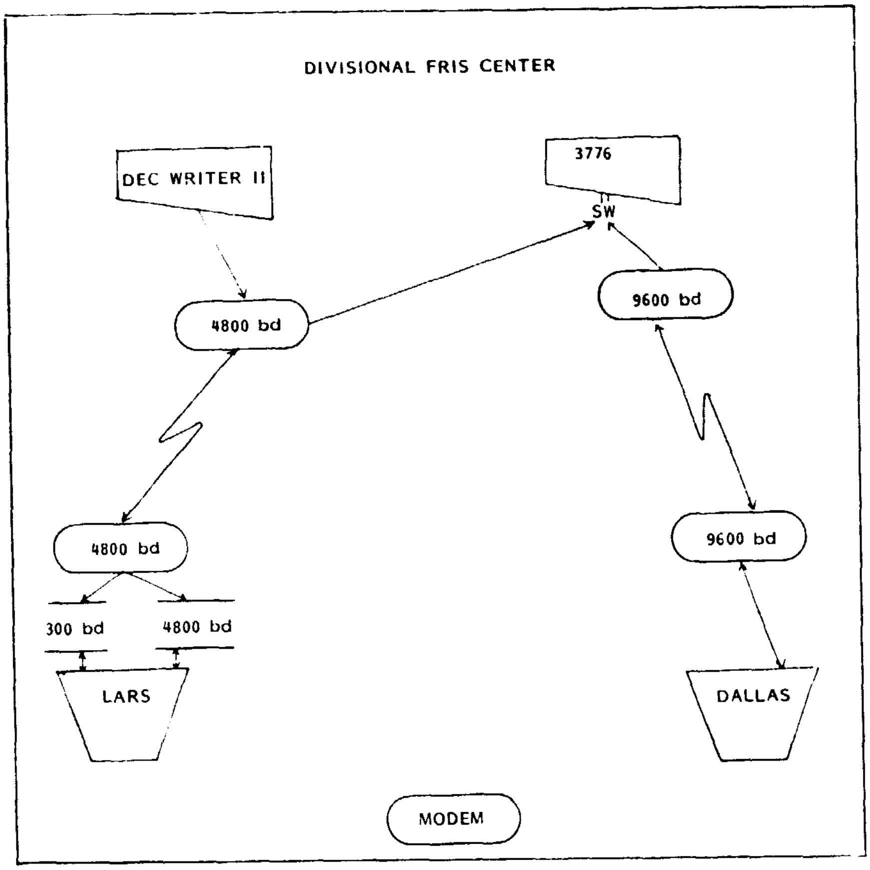

Figure 30 - STR/LARS Remote Terminal

4.222 Hands-on Training

Two one week sessions were held in Jacksonville by members of the LARS staff, where key St. Regis personnel were trained in the operation of the system and in analysis procedures. The software performed precisely as advertised and documented in the public domain, or as was presented in the experimental or developmental form. While the remote terminal between LARS and the DFC provided image processing hands-on training, this was only the beginning of the systems and technology transfer necessary.

Annotation and geographical referencing in a digital computer environment was a new experience to the St. Regis cartographic staff. Training in this field could not be done through a remote link. Potential FRIS staff personnel spent several weeks at the LARS facility learning the basics of digital data base construction and entry. Even this was rather rudimentary, since the LARS expertise was primarily oriented toward image processing. The graphics capability was only to the extent needed for spatial control. From the FRIS perspective, the digital map represented the geographic referencing essential in the operational utilization of Landsat data and the integration of this technology into the on-going information system. As such, the mapping system was considered as the cornerstone for the FRIS concept. From the LARS standpoint, the mapping function was strictly ancillary and a necessary inconvenience to accomplish the task at hand. It was clear, therefore, the graphics hands-on training provided by LARS was only an interim measure designed to acquaint St. Regis personnel with the notion of digital computer aided mapping techniques, and associated pitfalls.

4.3 The FRIS Design

The final FRIS design followed very closely the preliminary design already outlined. The major difference was the decision to pursue a turn-key option. With this decision made, a thorough review of the available systems was completed. Of the many reviewed, only a few were found to be compatible with the basic FRIS requirements in terms dealing with both gridded and vector formats, a data base manager to integrate the tabular attributes, and the interactive linkages that will permit the access to each independent data base.

It is clear, as the cornerstone of the FRIS concept, the geographical reference base must be amenable to receiving data with different formats. In addition, it must have the mechanisms to link the independent parts to the whole.

Some of the major considerations in evaluating available cartographic systems in light of the multiple functions involved in FRIS, included:

1. Input parameters

   a. What form is the map or source document in, grid or vector?
   b. Are the digitizing entry procedures interactive?
   c. Will the information be captured in layered format, and if so, how many layers of registered data are available?
   d. How dynamic or responsive is the updating and edit capabilities?

2. Manipulation of the data

   a. Are the major Boolean operators including intersection, union and complementary functions available? Are these capabilities extended to include interactive filtering such that the graphics file reflects interrogations through the attribute file, and vice-versa?
   b. Are there robust polygon processing capabilities beyond the Boolean operators, that will allow in-depth spatial analyses of forest conditions?
      - Proximity searches
      - Zones of isolation, exclusion or inclusion?

c. What are the modeling capabilities; for example, 3D models of terrain?

3. Output products

a. Regardless of the input format, will the output maps be available in user specified scales?
b. Can maps be produced with various line types with labels for each polygon entity?
c. What is the range of patterning capabilities; i.e., shading?
d. Will 3D diagrametric presentations be possible highlighting the magnitude of difference in relief?
e. Is there or will there be an operational remote station option with the system?

4.31 Vendor Selection

With these considerations in mind, the FRIS staff set about establishing a set of functional specifications for the evaluation of the FRIS system design alternatives. This would provide the basis upon which the vendors would be evaluated. These specifications are shown in Table 10, along with the scoring criteria. Three "turn-key" vendors were evaluated along with one configuration for in-house development. In order to be impartial, and to have a reasonable basis for comparison, each vendor was provided demonstration materials, and then asked to perform some specific tasks. Each vendor received the following data:

1. A map of four Administrative Units used in the Phase Two demonstration. These were the four AU's provided to Harvard University's Laboratory of Computer Graphics and Spatial Analysis. Their software, ODYSSEY, was being considered as part of the in-house configuration.

2. Full documentation of the maps content.

3. Tape containing digitized map information.

4. Documentation of digitized tape format and contents.

5. Tape containing Landsat classification data.

6. Documentation of classification tape format and contents.

With these materials in hand, each candidate vendor was asked to respond to the following data base manipulation requirements:

1. Produce a plot of the digitized data, containing the AU (Administrative Unit) and OA (Operating Area) boundaries for all four of the AU's.

2. The fourth file of the tape contained some extraneous points. Produce a clean plot demonstrating the editing capabilities.

3. Convert the Landsat classification data from grid to vector format.

4. Produce a plot of each layer of information.

   - AU boundaries
   - OA boundaries
   - Landsat classifications.

5. Associate attribute data with each layer of information

   - for the AU boundaries layer, the attributes would be the AU numbers.
   - for the OA boundaries layer, the attributes of interest would be the OA numbers, the forest type, and the age of the stand (this information was included on individual sheets describing each AU).
   - for the classification information, the required attributes would be the names of the classes taken from the classification results tape.

6. Produce an overlay of the three layers of information; namely AU and OA boundaries and Landsat imagery.

7. Graphically represent where the Landsat classification and the map are in disagreement for a cover type.

8. Demonstrate the capability to apply transformations to the vector data sets for rotation and scale manipulation.

While Table 10 is not an overly scientific approach to vendor analysis, it did provide a weighted empirical analysis of each. The vendor capabilities of Functional Tasks and Installation Components were judged as to completeness; complete (wt. 4), partial (wt. 2) and no capability (wt. 0). Future Enhancements were considered as merely a yes/no entry with yes carrying a wt. of 1 and no a wt. of 0.

Operational Factors and overall Vendor Analysis were judged as; good (wt. 4), "OK" (wt. 2), and poor (wt. 0). Future Enhancements were not applicable for these evaluattions.

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Table 10 - FRIS Functional Specifications and Scoring Weights for FRIS Vendor Selection

FRIS CAPABILITY

VENDOR CAPABILITIES	4 Complete/ good				2 Partial/ OK				0 None/ poor				Future Enhancement 1 Yes				Future Enhancement 0 No			
	VENDOR				VENDOR				VENDOR				VENDOR				VENDOR			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
I. FUNCTIONAL TASKS																				
A. GRAPHIC DATA																				
1. Input																				
2. Update																				
3. Analysis																				
4. Output																				
B. TABULAR DATA																				
1. Input																				
2. Update																				
3. Analysis																				
4. Output																				
C. IMAGE DATE																				
1. Grid to Vector																				
2. Vector to Grid																				
II. INSTALLATION COMPONENTS																				
A. HARDWARE																				
1. Configuration																				
2. Deliverability																				
3. Support																				
B. SOFTWARE																				
1. Availability & Cost																				
2. Transportability																				
3. Support																				
C. EXPANDABILITY																				
1. Remote Sites																				
2. Local																				
III. OPERATIONAL FACTORS																				
A. IMPLEMENTATION																				
1. Additional Cost																				
2. Time Required																				
B. CUSTOMER SERVICE																				
1. Short Term																				
2. Long Term																				
3. Responsive																				
4. User Group Activity																				
C. NCC INTERFACE																				
1. HASP/JES2																				
2. 3270																				
3. SDLC/SNA																				
IV. VENDOR ANALYSIS																				
A. EXPERIENCE																				
1. Overall																				
2. Forestry																				
3. Longevity																				
B. STABILITY																				
1. Financial																				
2. Credibility																				
3. Performance																				
SCORE																				

TOTAL VENDOR SCORE: A.________, B.________, C.________, D.________

After reviewing these benchmark results, it appeared only two vendors approached having the capabilities, at least in graphics, of meeting the basic FRIS requirements; however, no single vendor was able to do all that was asked. It was found, in general, that vendors and/or developers of new technology tend to extol the glories of the marvelous output products and ignore or downplay tremendously the less glamorous aspects of the activity, including the high level of labor intensity required to generate these products. Unfortunately, the potential user is often caught up in all the enthusiasm and does not find out until too late, just what his commitment to implementation means. One of the most positive aspects of the benchmark activity from the standpoint of FRIS was to force the candidates to lay it all out on the table. This left the FRIS staff with no illusions as to the effort confronting them in implementing the system.

Of the two surviving vendors, one system had a well developed data base manager in place and the ability to establish remote work stations tied into the host mini-computer at the Divisional FRIS Center. Both represented demonstrated capabilities, however, this vendor being basically in the Computer Aided Design (CAD) business, had no expertise in vector to grid/grid to vector transformation concepts. The second candidate claimed the transformation capability, but had no attribute management system at all, nor a demonstrated remote station capability. Of the lacking software availability, the generation of an efficient data base manager would be far more time consuming and difficult than developing the vector to grid/grid to vector software. This, plus the results of the benchmark evaluation provided the basis for the vendor selection.

4.32 The Divisional FRIS Center

In order to implement FRIS, three major St. Regis resource commitments had to be made as described in the preliminary system design; equipment, personnel and space.

4.321 Equipment

Figure 31 illustrates schematically the final FRIS hardware configuration. This follows closely with what was perceived in the preliminary system design. The summary of the hardware costs for this configuration is outlined in Table 9 (page 57). Table 11 is a description of the hardware configuration as finally installed.

It should be noted that the 300mb disk drive illustrated in Figure 31, was added shortly after installation and is not reflected in the hardware list in Table 11. Here the original two 80mb disk drives are listed.

For typical forestry applications such as FRIS, 80mb disks are just not adequate nor is the PDP 11/70. Shortly after installation, both 80mb disks were upgraded to 300mb units and the PDP 11/70 to a VAX 11/780 with one megabyte of memory.

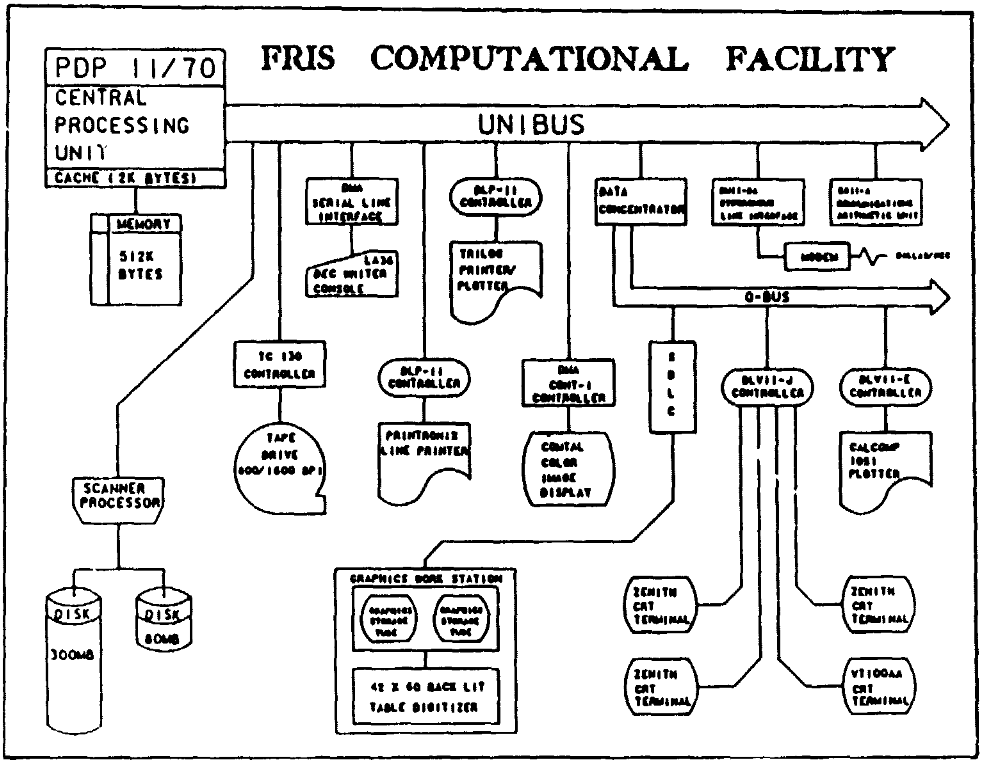

Figure 31 - Schematic of the FRIS Hardware Configuration

Table 11 - FRIS Design - Final Hardware Description

A. MINI-COMPUTER SYSTEM
   1. Data Processing System
      a. PDP 11/70 Central Processor with 1/2 Megabyte of MOS/ECC Memory and Floating Point Processor - DEC
      b. Data Concentrator - Special Manufacture
      c. DECwriter II System Console - DEC
      d. Disk Data Scanner - Special Manufacture
      e. 9-Track Duval Density Tape Drive and Controller - DEC
   2. Two Disk Drives, 80-Megabyte
   3. Two Disk Packs
   4. Synchronous Line Interface - DEC
   5. Communications Arithmetic Unit - DEC

B. INTERACTIVE GRAPHICS TERMINAL CLUSTER
   1. Display System - Two (2) Graphics CRT's (Tektronix 4014-1)
   2. Input System - 42 x 60 Backlighted Digitizing Table with Adjustable Base - TALOS

C. DRUM PLOTTER, Calcomp, Model 1051

D. 4 VIDEO DISPLAY TERMINALS, ALPHANUMERIC (DEC)

E. COLOR IMAGE DISPLAY UNIT, COMTAL Model "Vision One/20" Complete (COMTAL)

F. MATRIX PRINTER, Printronix P-600 with Carbide Tips, Static Eliminator, and RS232 Interface, PDP 11 Controller

G. LINE PRINTER

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In addition to this lengthy hardware configuration, is a considerable software requirement. Throughout the entire FRIS project, one recurring caveat emerged that should be emphasized: there is a tendency to under-estimate software needs, not only initially, but as a continuing commitment. Table 12 an extension of Table 8, has been prepared to give some insight as to the magnitude of the software required, not all of which was obvious (or understood) at the outset.

Table 12 - FRIS Software Description

DESCRIPTION
Systems Training
1051 Plotting Software (On Line) Drum Plotter
HASP Emulator Package Software Interface to IBM equipment at the St. Regis National Computer Center
Graphics Design Software
RSX-11M Operating System Software Licence PDP 11/70 Operating System
Bulk Input Text Software Provides the linkage from input text to the graphics file design through text nodes
FORTRAN IV-PLUS Software Licence FORTRAN Compiler
Elastic Body Software To allow data of many shapes and scales to be integrated into a single file - "rubber sheeting"
Data Base Management Software
World Mapping Software Transformation from latitude and longitude to any other coordinate system desired; e.g., State Plane, Transverse Mercator, Lambert Conformal
Miscellaneous Software Packages and Services

All the software described in Table 10 is available off the shelf. It barely scratches the surface in describing the software requirement to meet the specific needs of the organization. In-house software support is absolutely essential if FRIS is to be a responsive and accessible system.

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4.322 Personnel and Staffing

As of April 1, 1980, the FRIS Section became an integral part of the Research and Technology Department of the Southern Timberlands Division. The organizational structure of FRIS is primarily the same as it was in the Preliminary System Design, but there are a few significant changes that were made for the final design configuration; Figure 32. The primary changes involve the Senior Digitizer and the Remote Sensing Technician. The Senior Digitizer had to become a machine room supervisor with two qualified digitizers. Work schedules, job allocation and quality control are the major areas of this person's responsibility. Also somewhat of a misnomer, the Remote Sensing Technician needs to fill an important gap, that of attribute data management. This not only involves the data base management tasks, but the integration of the current data base into the FRIS format. There is also a need to transform the advantages of control over prior knowledge into sample design efficiencies.

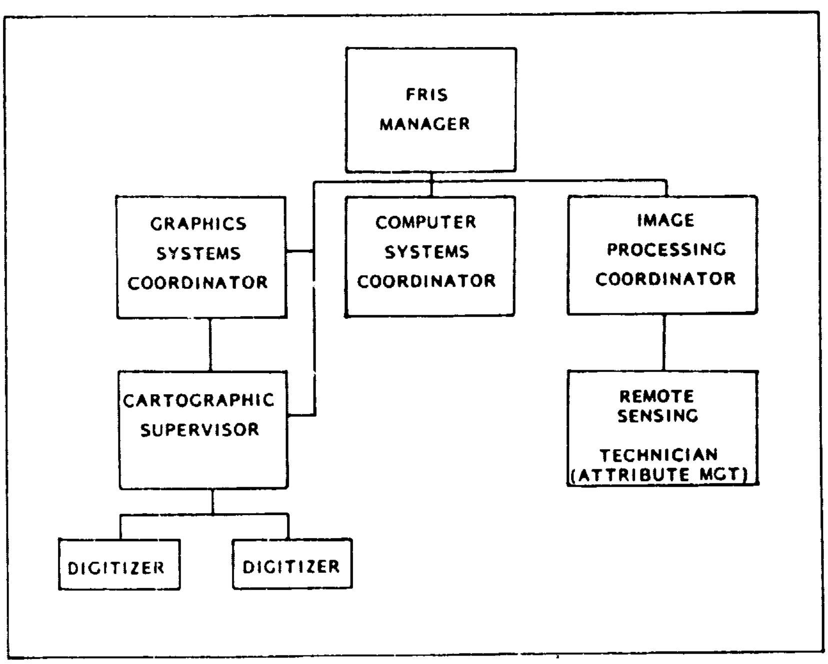

Figure 32 - Final FRIS Organization Chart

It has been said that the most efficient form of technology transfer is to transfer the technologist. To fill the positions outlined in the above Organizational Chart, St. Regis did just that, from both outside and within the Company. While the size of the staff is minimal if not indeed "bare bones", it is of high quality and dedication, a positive sign toward successful implementation.

4.323 Space

Existing space as was available at the divisional headquarters was simply inadequate to house FRIS or any of its parts. New facilities were provided in a new office building within five miles of the Southern Timberlands office building, where along with Technical Forestry and Maps and Surveys (two closely related activities), FRIS set up shop. Containing in excess of 4,000 square feet, the facility was built out to FRIS specifications. St. Regis had lived up to its commitments with regards to equipment, personnel and space. It was now up to the FRIS staff to carry on to successful implementation.

4.4 FRIS Implementation

The final phase of the FRIS project; implementation, represents at once the end and the beginning; the end of the NASA/STR/LARS cooperative, and the beginning of FRIS as an operating entity. The following describes the structure, major milestones and tasks to be performed before FRIS can be declared fully operational. During this period, a test case will be entered into the FRIS format, with required output products generated, and retrieval capabilities demonstrated. This case will serve as a training ground to "shake out the image processing and interactive mapping systems and to establish efficient operating procedures in terms of data flow, capture and updating.

As part of the implementation task, the transition of the on-going departmental data processing activity into compatible FRIS formats will be done. The objective is to integrate current procedure such that one forest resource information system will emerge which is responsive to the range of user needs within the Division (2).

4.41 The FRIS Structure

The FRIS structure as described in the personnel section above, revolves around the organizational chart in Figure 32. A brief overview of the functional responsibilities of FRIS Management and the four primary discipline areas of imagery, cartographics, computer systems and attribute management is presented below.

FRIS Management

- Overall coordination of FRIS activities
- Administration and organization toward achieving FRIS implementation objectives
- Training and technology transfer

Graphics Systems Coordinator

- Coordination of the data capture and file certification activity
- Inter-departmental liaison with Land Records and Survey
- Evaluates and interacts with outside vendors for standard or automated data capture

Cartographics Supervisor

- Basic production aspects of establishing, maintaining and modifying the cartographic data base
- Generates training guides and production schedules
- Procedural documentation and quality control

Remote Sensing Coordinator

- Coordinates all digital image processing activity including; pre-processing, classification, training and technology transfer
- Develop user oriented output products and produce procedural documentation
- Spectral analysis research

Remote Sensing Technician

- Explore concepts and develop procedures linking remotely acquired data to ground sampling techniques
- Develop modeling techniques allowing FRIS to take full advantage of the prior knowledge afforded by satellite imagery and organized by the interactive graphics system
- Landsat classification validation procedures

Computer Systems Coordinator

- Coordinates the FRIS computer services as relates to the mini and host computers, graphics work stations and the peripheral support hardware
- Serves as the FRIS systems manager, providing technical liaison with the various systems vendors
- Directs the FRIS software development, installation, maintenance and update.

4.42 FRIS Milestones and Tasks

The implementation of FRIS into an operational system will point toward eleven major milestone objectives. Each milestone represents a documentable event which will be compiled in a FRIS policy and procedures manual upon completion. Within each discipline, operational procedures and "cook book" documentation will be provided to insure compatibility and continuity of the major FRIS functions.

The major milestones are outlined in Appendix D. A time line of completions is illustrated in Figure 33.

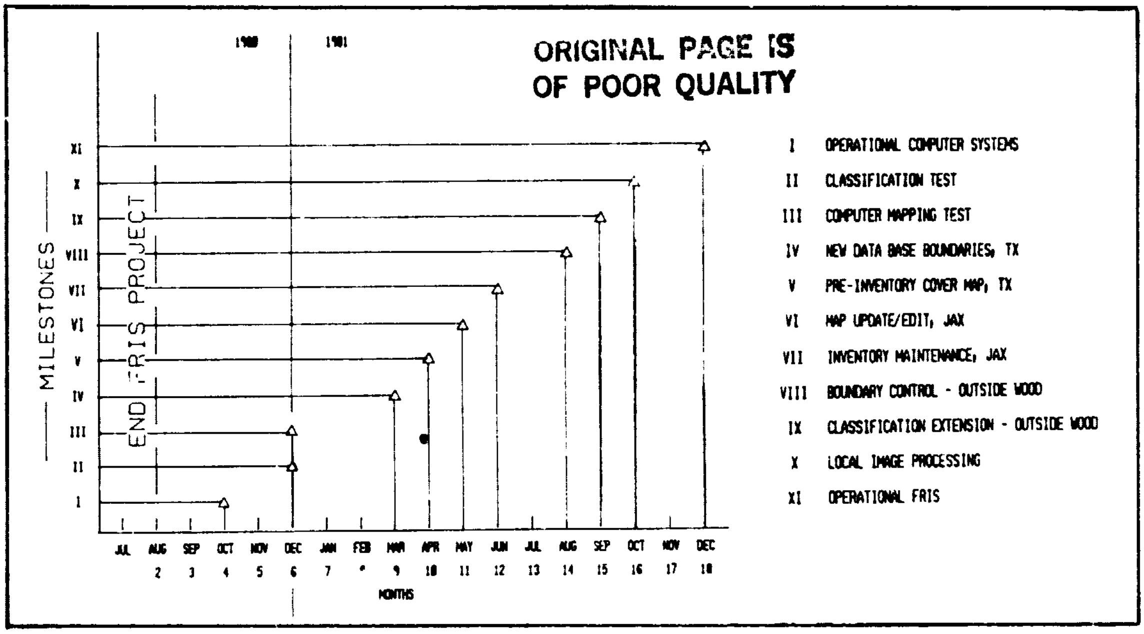

Figure 33 - FRIS Implementation Milestone Chart

The major production aspects of FRIS implementation involve remote sensing and cartographics. Computer systems represent a tool for data reduction, analysis and display, while FRIS management represents co-ordination and administrative support.

Parallels exist between cartographic and remote sensing milestones and tasks. This reflects the interdependence of the two functions. It should be noted that the third major forest data function, attribute management, will be addressed by the Remote Sensing discipline with assistance from the Remote Sensing Technician.

The major objectives of FRIS implementation are to:

1. "Shake down" the hardware-software component

2. Train in-company personnel in a system that operates in a production environment

3. Test and verify those areas where FRIS improvements over the current system are expected

4. Generate the policies and procedures under which FRIS will be driven.

In support of these major objectives and as reflected in the Milestone Chart, Figure 33, implementation has been subdivided into four major segments: test and evaluation, prestratification and sample design, in-place inventory (monitor, update and maintenance) and outside wood supply. Successful demonstration of prestratification and outside wood supply will also satisfy the requirements for potential acquisitions.

A brief description and desired results from each of the four segments follows.

Tests and Evaluation

Tests and evaluation is designed primarily for "shake down" and procedural development of the system. An area large enough to represent the diversity of situations and small enough to be manageable was desired. Test Site II from the Phase II demonstration was selected as meeting the basic requirements of such a test and evaluation and is an area of vital information need within the Division. This area, in southeast Mississippi, is adjacent to NASA's National Space Technological Laboratory in Bay St. Louis. Test and evaluation proceeded concurrently in the cartographics and remote sensing functions.

Procedure

The following outlines in chronological fashion the procedures and projected accomplishments of this training and evaluation period.

1. Cartographics

   a. Inputs

      (1) Gather all base maps and support photographs available

      (2) As soon as basic training permits, enter[1] the basic map data from the 1980 map-set. These maps have the most accurate boundary annotation. The completed data base will consist of mutually exclusive layers or levels of information all registered to a common base; thus the levels are combinable. One of these levels will be forest cover types

      (3) The forest cover type level will be generated from 1972 data and registered to the 1980 base

      (4) In addition, 1975 forest cover type levels will be generated and registered to the 1980 map base

      (5) Hurricane Camille (1969) damage intensity zones will be entered as a separate level of data

   b. Outputs

      From the historical map file the following will be provided

      (1) The gross change in forest cover type over the eight year period

      (2) Periodic change coincident with required reports depicting spatial distribution of the reported general cover types, i.e., natural pine, planted/seeded pine, pine-hardwood/hardwood and non-stocked

      (3) Highlights of change r ecting harvest, regeneration, natural disaster and cultural activity

[1]Enter here and throughout this report means entering into the FRIS interactive mapping file.

2. Remote Sensing

a. Inputs

(1) Anniversary data have been ordered from the EROS Data Center for the years 1972 - 1980 (9 scenes). This is the period of time in which Landsat has been operating

(2) All scenes will be displayed in false color to select the best scenes, in terms of quality, to coincide with the periodic map coverage

(3) Train and classify scenes

(4) Reconcile classification with appropriate map bases

(5) Analyze and assess results

b. Outputs

(1) Geographically referenced pictorial profile of the test site forest cover; 1972-1980

(2) Highlights of change both expected and unexpected

(3) With supporting map base to show current cover type distribution vs. the distribution at the time of first Landsat coverage in terms of natural pine, planted/seeded pine, pine-hardwood/hardwood, non-stocked and others. All outputs will be produced in displayable format

<u>New Lands Entering the System (Acquisitions) - Texas</u>

The major thrust of this activity is to demonstrate and develop procedures for prestratification using Landsat data in order to optimize field sample allocation. During this stratification, maximum data extraction capability will be attempted with documented results. Since the cartographics systems provides geographical control, it will be done in parallel or slightly before the image processing effort. A brief chronology of events follows:

1. Order and secure Landsat data for Texas.

2. Investigate vendors for data entry. Only one data entry station is available in-house -- need to negotiate with potential vendors and look into automated digitizing as offered by various vendors.

3. Enter Texas survey boundaries on file with Texas Maps and Surveys.

4. Select and train Texas digitizer if utilizing outside facilities is indicated.

5. Enter significant additional boundaries and cultural features. This will provide the framework for Landsat analysis.

6. Train and classify Landsat data. Within the pine types extract areas with significant features differences. Try to correlate with stand structure, specifically sawtimber stands. This procedure will include multi-data and ratios of spectral bands.

Inplace Inventory - Maintenance, Update - Jacksonville

The primary thrust of this activity is to develop a scenario for annual updating and maintenance of the data base; inventory and maps. All parts of FRIS shall be exercised including: digital imagery to monitor the scene, descriptive inventory in standard updating format and interactive mapping to plot change. In addition, the linkage from digital images to photograph to ground will be established.

To accomplish this, a relatively small area has been selected as a test case, the Knabb tract in Baker County, Florida. The sequence of events is as follows:

1. Order and procure scene.

2. Enter Knabb tract in detail into the system.

3. Provide the graphics - attribute linkage required through updating format.

4. Train and classify Knabb tract.

5. Enter classified results into map file with attributes being transferred to tabular data base file.

6. Select areas for double sampling.

7. Design photo plot sample and ground sample subset and secure data.

8. Carry out correlation and generate correction regression.

9. Provide inventory report in update format and field check.

10. Document results and establish procedures.

Outside Wood Supply - Selected Sites Throughout the Division

The purpose of this activity is to evaluate the feasibility of utilizing St. Regis lands as a viable training set for other forested land within a Landsat scene. This will be tested by training on St. Regis land and extending the statistics generated to pertinent surrounding lands. To establish pertinence, boundary control must be entered into the system. This includes the Census Bureau's Dual Image Map Encoding (DIME) file which consists of digitized county boundaries. In addition, major outside ownerships both public and private will be entered. The sequence of events is as follows:

1. Enter and annotate the DIME file.

2. Select divisional training areas to be permanently established.

3. Select and order data for training areas (two seasons if possible, and anniversary dates on a select few).

4. Enter county cultural and major physiographic features.

5. Enter major outside ownership boundaries

6. Enter St. Regis property boundaries of training areas into map base.

7. Classify training areas.

8. Extend results to surrounding counties. Issue current and change reports on each county including an acreage and map of cover distribution and change.

As of this writing implementation is still progressing. Some of the sites have been changed and experience has altered some of the approaches. Basically, however, FRIS implementation has followed the general outline as annotated above.

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APPENDIX A

KEY PROCESSORS IN THE LARS IMAGE PROCESSING PACKAGE

Processor	Function
PICTUREPRINT	Line printer gray scale map of the scene or portion thereof to be processed. Used primarily for selecting training sites. Deals with raw data only.
CLUSTER	A set of algorithms that will cluster data values within the scene of interest into a user defined number of groupings. In forestry applications, usually between 9 and 15.
SEPARABILITY	A procedure that evaluates the cluster groupings and combines those groups so similar as to make their separability into definable classes improbable. With up to 15 cluster groups, this is usually no problem. It comes into play when combining several training clusters where like features are combined, as after MERGESTATS.
MINDISTANCE	Extends a cluster block to include an entire Administrative Unit. It is really a classifier.
MERGESTATS	Merges the statistics from several training areas into one data deck.
BIPLOT	Produces a bi-spectral plot of classes and their means, as contai ed on a statistics deck.
CLASSIFYPOINTS	The process of using the training statistics to classify an area of interest into meaningful features. The processor assigns each pixel in the data to a unique class using either of two algorithms; maximum likelihood or the minimum distance rule. The results are written to tape or disk.
PRINTRESULTS	The means to depict in a gray scale map format printed classification results. It also tabulates the number of pixels assigned to each class.

APPENDIX B

FRIS IMAGE TRAINING AND CLASSIFICATION PROCEDURES

During the FRIS project, standard training and classification procedures were followed as defined by LARS. As the Phase III Systems Transfer task was completed, and the FRIS Center established, significant changes were made to put the image processing activity into a production environment. Described below are the standard LARS procedures followed during the Phase II demonstration, and a description of the major operational changes made to accomodate FRIS.

I. FRIS Project - Standard Training and Classification Procedures

A. Data Set Generation

1. Define permanent training units. These should:

   a. be large and diverse enough to include the range of expected spectral classes within the tract.

   b. be geographically representative of the tract.

   c. represent a cross-sectional profile of the tract, both in terms of geology and vegetation.

   d. endeavor to include entire Administrative Units or similar geographically referenced areas.

   e. at the scale of the source maps, be flexible to allow for partial area replacement if required.

2. Clear acetate overlays should be obtained:

   a. for each Unit selected for training.

   b. updated in response to significant cultural change.

   c. permanently archived for immediate reference.

3. Boundary annotation should be made for:

   a. all Administrative Unit boundaries within each test area including the training units.

   b. all AU and Operating Area boundaries.

II. Classification Training Procedures

1. To be carried out on each training unit within each tract.

2. Generate line printer output (PICTUREPRINT)[1] for each training unit defined in A above.

   a. For a given run (scene), line and column range with appropriate interval will be defined such that the range in both lines and columns will encompass the entire training unit.

   b. Gray scale. (PICTUREPRINT/ G DATA) displays only one channel at a time. The channel best suited to locational information should be used, i.e., one of the visible channels. Used primarily to pick cluster blocks.

   c. Unless the analyst has preference, the symbol array offered by the default option is generally satisfactory for this gray scale print-out.

3. Select cluster blocks within selected Administrative Units.

   a. Blocks will fall wholly within the boundaries of the AU in such a way as to be as inclusive as possible.

   b. As many rectangular blocks will be generated as needed to properly represent the range of conditions within the unit.

   c. For efficiency, cluster blocks should range from 2500 - 5000 pixels (50 x 50 - 70 x 70) - blocks do not have to be square.

4. Clustering. (CLUSTER/SEPARABILITY)

   a. In clustering an arbitrary 15 classes will be designated based upon the standard size defined in 3c above. Other sizes will be considered as exceptions to this rule.

   b. SEPARABILITY will always be run behind CLUSTER as a matter of form.

   c. Analyst check point - with 15 cluster classes, little or no combining of classes is expected at this stage of the process; for example, check separability means against expected ranges in both the visible and IR for obvious irregularities.

5. Minimum Distance Classifier. (MINDISTANCE) - Purpose is to extend the 15 cluster classes to the boundaries of the pictureprint block.

6. Associate Cluster classes with information classes.

   a. This process done for each training unit within the tract.

   b. Statistics deck generated and placed on temporary disk.

[1] Capitals indicate LARSYS Processors.

c. Utilize data from SEPARABILITY to aid in identifying and combining classes.

d. The overlayed map and associated aerial photographs should also be helpful.

7. Merge the statistics from all training units. (MERGE)

a. As decks are merged, combine like classes, checklines, with the various unit maps and photographs and other ground truth (updating) as available.

b. Keep going through the MERGE procedure until one classification deck results.

8. Classify - (CLASSIFY)

a. If any doubt exists, classify small sub-unit to verify training.

b. Select symbols indicative of the classification features to be emphasized.

II. Procedural Training Changes Brought About by FRIS Establishment

During the course of the project (Phase II) the definition of training sets was based on the clustering of blocks of data and subsequent identification of the cluster classes by relating their location and pattern to maps and photos. However, the procedures used to identify the cluster classes changed in the latter stages of the project. Initially the only output was line printer maps of the clustered area. The product is limited in use because of the well known problem of representing classes with a printer symbol. Even though this was for many years the usual map product, it remains a poor image that is lacking in contrast and is often visually confusing. One procedure used in an attempt to improve the cluster map was to classify an area larger than the cluster block using the cluster statistics. While the larger map is somewhat easier to interpret, it still remains a line printer product with its inherent deficiencies.

With the establishment of the FRIS facility in 1980, a significant change in training procedures was initiated with the use of the Comtal digital display unit. Not only is the image quality far better, but the addition of color and multiple image planes provides the analyst with several options never before available. The use of maps and photos is much easier due to the improved image quality and the false color composite image. Additionally, the image represents a much larger ground area than is available in photo coverage. This image, normally 18 miles on a side, provides contextual information as well as the usual false color information. Frequently subtle variations in cover types can be found and included in the training set by clustering the areas where they occur. Another technique that has been added is that of loading a trial classification onto one image plane and the corresponding data into the other image planes. The data is then

displayed as a false color image and the classification is assigned colors to represent the various information classes. The analyst may then alternately view the classification and the data to see if any discrepancies are present. In a similar procedure the first determination of training classes can be made using image interpretation of the false color presentation in lieu of, or in combination with, maps and photos. The procedure requires that a clustering of data be done to generate a statistics set which is used "as is" to classify a block of data. Then color is assigned to the classification one class at a time and the class is identified by observing where it appears on the false color data image. The effect is similar to having acquired high altitude photography concurrently with the data. Assigning class names in this manner does require that the operator be familiar with the cover types present at the time of data collection and have experience in interpretation of false color imagery. It is most useful when working in an area where no maps or aerial photography are available.

These changes in analysis procedures have improved the accuracy of the training sets and reduced the time needed to produce them. They are indicative of a rapidly evolving technology and most certainly will be modified as new equipment and different operations appear in the future.

APPENDIX C

FRIS - THE OPERATIONAL CONFIGURATION

The general flow as perceived in an operational FRIS is described below and illustrated in Figure C-1. It will be noted that the image processing task is a pre-updating activity; thus, the receipt of image data must fall in the window between October and January, if possible, to assure it will be available for the updating cycle. For ease of handling and processing, the Division will be subdivided into Resource Information Blocks (RIB) approaching some 100,000 acres each. This is subject to change with experience.

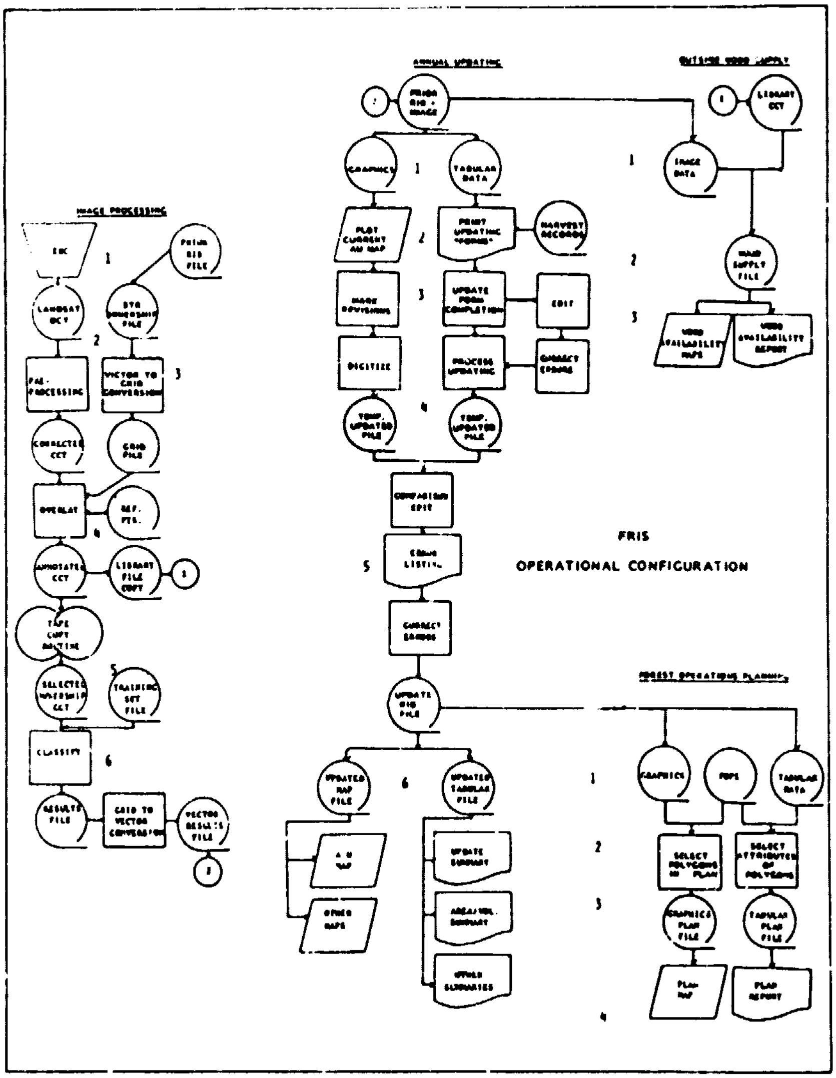

Figure C-1 - FRIS - Idealized Operational Flow

Included in this description is the interface to the Forestry Operations Planning System Models (FOPS) and outside wood supply, including potential acquisitions.

Image Processing

1. EDC - Data must be ordered from the EROS Data Center in Sioux Falls, South Dakota.

   - Some 20 scenes are required to cover the area of interest.

   - Largest effort and order to be made in the fourth quarter, October 1 - December 31. The later in the quarter the better.

   - Scenes must be previewed. Even with 80-90% cloud cover, the area of interest may just be in the clear window; of course, the converse is also true.

   - Data in the form of CCT's will be delivered to the DFC in Jacksonville, FL.

2. Pre-Processing

   - Upon receipt of the CCT's the data must be reformatted, and the scene geometrically corrected.

   - A corrected Landsat CCT will be generated and sent to Dallas, TX.

3. Vector to Grid Conversion

   - Southern Timberlands ownership file derived from existing RIBS will be generated.

   - The vector to grid conversion will be done as appropriate and a grid file generated.

4. Overlay (registration)

   - The ownership file in grid format will be overlayed on Landsat data.

   - Ground reference point data file for St. Regis ownerships will be accessed on an image display unit.

   - Precision registration on pertinent lands will be done on image display CRT.

   - Annotated CCT will be generated.

   - Results of the registration process will be verified for accuracy.

- Upon verification, a tape copy routine will be done, with one CCT filed as a library copy.

5. Training

   - From the annotated CCT, a selected ownership file will be generated at the Divisional FRIS Center (DFC).

   - Selected ownership CCT and the training set file will be utilized to cluster and identify pertinent forest related features. These features will be those recognized as separable entities by computer analysis.

   - All training sets will be processed into one merged training file.

6. Classify

   - Utilizing the training statistics in the merged file, the selected ownerships will be classified.

   - A classified results file will be generated.

   - This ends the image processing sequence. The classified image in grid format can be converted to vector format.

   - Vector results file returned to the RIB as pre-updating image file. (This could also be done in gridded format. Experience will guide the procedure here.)

Updating the Data Base

1. Update Files

   - With new imagery in hand, prior graphic and tabular data files are generated.

   - Graphic and tabular data will be updated concurrently.

2. Forms

   - Current AU map is plotted for use in updating.

   - Updating forms are printed in CRT format.

3. Update

   - Revisions on the map are marked and delineated.

   - Updating form is filled out on CRT.

4. Compile Updated File

   - Map revisions are digitized and edited by graphic CRT.

   - Updating is processed after being edited.

   - Temporary files are generated for the graphics and tabular data.

5. Reconciliation

   - The graphics and tabular data are screened for errors and inconsistencies.

   - From the error listing the errors are corrected and the file reconciled.

6. Update File

   - The updated graphics and tabular data are added to the RIB file with the current imaged data.

   - The updated RIB includes image, graphic and tabular data to a point in time.

Other Applications

The updated RIB file can be partitioned into its ownership component and directly applied to the FOPS file. Past activity both in terms of quantitative values and spatial distribution can be described. In addition, a plan report and map can be generated for the current year or future year's activity. With use, there is little doubt of the expanded use of FRIS in this area.

Outside Wood Supply

It must be recognized at the outset that to use FRIS in an outside wood supply environment, pertinent layers of information must be digitized and in the system for control. In addition to the St. Regis boundaries already discussed, the following must be included as a minimum.

1. County boundaries - throughout the wood drawing area of the Southern Timberlands all potential counties must be annotated. Such a data file is already available from the U. S. Census Bureau. Called DIME, this file has all the counties in the 48 contiguous states in digital form; Figure C-2. While the accuracy of some of the boundaries may leave a little to be desired, it is a point of departure.

C - 2

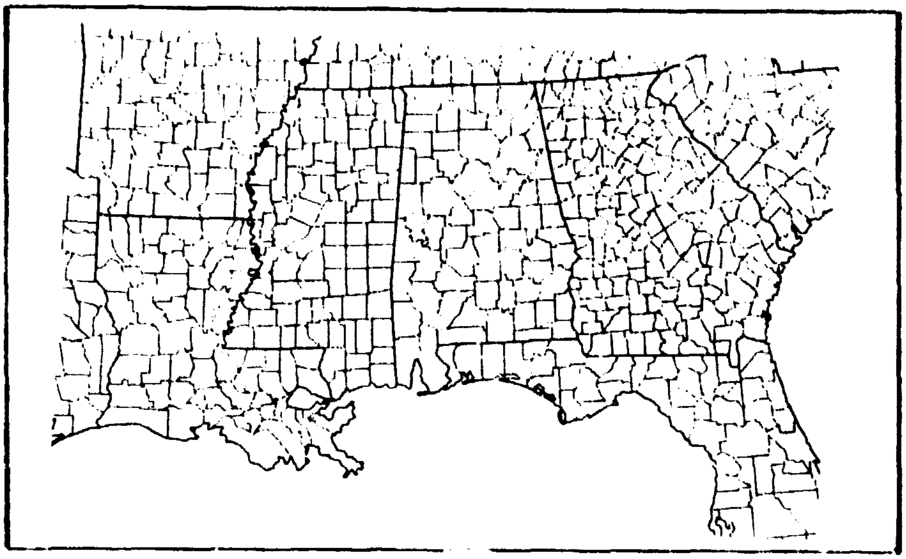

Figure C-2 - U. S. Census Bureau - DIME File of County Boundaries in the Southeast

2. Principal Outside Ownerships

   a. Non-Available Timber

      . Other industrial ownerships
      . National Parks, Monuments

   b. Marginally Available Timber

      . U. S. Forest Service
      . Large private ownerships where sales occur from time to time.

   c. Other lands - potentially available timber.

3. Basic transportation networks - railroads, highways.

4. Major drainage indicating physical availability.

5. Strategic point information (rather than line or polygon); for example, woodyards, manufacturing facilities, towns, etc.

The library file CCT will be used as input. In this case, it has not been classified. Using the classified image data in the RIB data base for training, the area of interest will be classified. Although the training in some cases may be light, or non-existent, classification into pure, hardwood and mixed and non-forest lands can be accomplished based upon current knowledge. This capability will provide data pertinent to:

> Growth and drain by County - in terms of acreage, the addition or deletion of forest land, pine or hardwood and where it occurred.

- Area of major forest types and where they occur.

- Identification of all outside lands by major ownership.

- Point search - from any point previously identified, to search within any prescribed radii and document the acres of various cover types.

- Utilizing the graphic capabilities of FRIS, to plot out any area or condition in need of highlighting.

- Assist in county tax appraisal by quickly indicating gross acres of pine, hardwood and non-productive and plotting out these acres as special map products.

APPENDIX D

MILESTONE EVENTS AND TASKS REQUIRED FOR FRIS IMPLEMENTATION

Listed below are the major task elements involved in achieving the milestones as set forth in the FRIS implementation plan. Each milestone is identified with the responsible FRIS function. Since these activities represent a first in many cases, it is anticipated the task definition will change as experience and priorities dictate.

MILESTONE EVENT	DISCIPLINE AREA
I. Operational Computer System	Computer Systems

Tasks

A. COMTAL Display, False Color
B. Enhanced polygon processor
C. Vector-to-Grid-to-Vector software implementation
D. Results[1] to Graphics
E. HASP emulation to the St. Regis National Computer Center

II. Classification Results Test	Remote Sensing

Tasks

A. Procurement of Test Site data
B. False Color profile 1972 - 1980
C. Annotate scenes
D. Classify anniversary dates
E. Analyze results
F. Design output products
G. Document results and procedures

III. Computer Mapping Tests	Cartographics

Tasks

A. Train and select digitizing person
B. Enter 1980 Test Site Data
C. Enter 1972 Test Site Data
D. Reconcile imagery with period photos and maps
E. Output product design
F. Document results and procedures

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[1]Results refers to Landsat classification results

MILESTONE EVENT		DISCIPLINE AREA
IV.	New Data Base Boundaries, Texas	Cartographics

<u>Tasks</u>

A. Evaluation of outside vendors
B. Enter Texas Region Survey data
C. Select and train Texas Region digitizing person
D. Enter basic Texas Region boundaries and cultural features
E. Begin entering data from inventory

V.	Pre-inventory Cover Map	Remote Sensing

<u>Tasks</u>

A. Select and order data
B. Train and classify data
C. Maximize extraction capability
D. Highlighted output products
E. Document findings

VI.	Map Maintenance, Update - Jacksonville	Cartographics

<u>Tasks</u>

A. Digitize test site - Jacksonville Region
B. Link inventory data base to map entities
C. Enter classification results into the map and attribute data files
D. Update and edit tabular and map data
E. Document results and procedures

VII.	Inventory Maintenance, Update - Jacksonville	Remote Sensing

<u>Tasks</u>

A. Select and order data set for Jacksonville Region Test Site
B. Train and classify
C. Evaluate change from prior data
D. Select candidate ground sampling areas
E. Carry out double sampling
F. Reestablish updating values - check
G. Document results and procedures

MILESTONE EVENT		DISCIPLINE AREA
VIII.	Boundary Control, Outside Wood - Selected Sites -	Cartographics

Tasks

A. Establish and annotate county DIME File as part of FRIS
B. Enter major cultural and physiographic features within county
C. Enter major outside ownerships with appropriate attributes
D. Enter boundaries of training areas
E. Document results and procedures

IX.	Classification Extension, Outside Wood - Selected Sites -	Remote Sensing

Tasks

A. Select areas for training
B. Select and order data
C. Train and classify sites
D. Extend results within scene
E. Generate county statistics
F. Document results and procedures

X.	Local Image Processing Capability	Computer Systems

Tasks

A. Comtal color class
B. Comtal graphics boundary overlay
C. LARSFRIS capability locally
D. Preprocessing
E. Documentation

XI.	Operational FRIS	Management

Tasks

A. FRIS project final report - documentation
B. Implementation
C. FRIS Conference
D. Integration of on-going system
E. Multi-functional data base management system
F. Divisional education and training procedures
G. Implementation priorities
H. Audit and financial evaluation design
I. Policy and procedure
J. Documentation